# Background Document for Life-Cycle Greenhouse Gas Emission Factors for Carpet and Personal Computers

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## EXECUTIVE SUMMARY

This paper describes the methodology and data sources used to develop greenhouse gas (GHG) emission factors for carpet and PCs. The paper is intended for readers interested in understanding the technical underpinning behind how the factors were developed. The emission factors presented below are the latest in a series of emission factors developed by the U.S. Environmental Protection Agency (EPA). EPA's research into the link between GHG emissions and waste management began in 1994 and continues today. In 1998, EPA published *Greenhouse Gas Emissions from Selected Materials in Municipal Solid Waste*, which presented the methodology for conducting a life-cycle assessment of the GHG impacts of waste management for commonly-recycled materials in the municipal solid waste stream. The key results of the report included life-cycle GHG emission factors for 12 materials and 5 waste management options: source reduction, recycling, composting, combustion, and landfilling. These emission factors were the basis for a user-friendly spreadsheet tool called the WAste Reduction Model (WARM). WARM was designed to assist waste managers in quantifying the GHG benefits of their waste management practices.

As research on life-cycle impacts of waste management practices on these and other materials progressed, it became necessary to update both the report and WARM. Both were updated to include: (1) new data on energy and recycling loss rates, (2) an improved analysis of the GHG benefits of composting, (3) emission factors for several new material types and new categories of mixed materials, (4) new energy data for the calculation of utility offsets, (5) revised carbon coefficients and fuel mixes for national average electricity generation, and (6) updated information on landfill gas recovery practices. The revised report, published in 2002, is entitled *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks*, and covers 16 individual materials found in the municipal solid waste stream (e.g., aluminum cans, newspaper, dimensional lumber) and 7 categories of mixed materials (e.g., mixed paper, mixed plastics).[1]

All emission factors included in the first and second versions of the report have focused on either specific materials (e.g., steel cans) or mixed materials (e.g., mixed recyclables). In 1999, EPA began investigating the feasibility of developing product-level emission factors. This paper describes the methods EPA used to apply the life-cycle approach presented in the 1998 and 2002 reports to two composite products: carpet and personal computers (PCs). The complexity of these emission factors necessitated a separate report documenting the methodology, data sources, and assumptions we used.

EPA's interest in carpet grew out of an expanding effort in the area of product stewardship. Over the past several years, EPA has worked with carpet and fiber manufacturers, the Carpet and Rug Institute, state governments, and non-governmental organizations to develop a voluntary product stewardship agreement on carpet. These efforts culminated in January of 2002 with the signing of a National Carpet Recycling Agreement.[2] This agreement sets a national goal of diverting 40 percent of end-of-life carpet from landfill disposal by 2012. A product level GHG emission factor for carpet will enable EPA to help quantify the climate benefit of recycling and reusing a continually increasing quantity of used carpet as the parties to the National Carpet Recycling Agreement work towards meeting its goals. In 2000, carpet and rugs accounted for 2.6 million tons of waste in the US, representing 1.1 percent of the total U.S. wastestream.[3] According to EPA, only 30,000 tons, or 3.6 percent of total waste generation, was recycled in 2000, up from negligible recovery in 1990.

EPA's interest in understanding the GHG impacts of waste management for PCs was threefold. First, electronics are among the most rapidly growing categories of the U.S. wastestream. Sales of electronics have been increasing dramatically, and due to the fairly short period between purchase and discard, sales are expected to grow significantly in the future. Second, electronics contain valuable materials that can be reused and/or recycled,

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[1] Report is available online at the following website: <yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteToolsReports.html>.

[2] For additional information on this product stewardship agreement see Carpet America Recovery Effort's (CARE) website at: <www.carpetrecovery.org/>.

[3] EPA, 2002. *Municipal Solid Waste in the United States: 2000 Facts and Figures*. Office of Solid Waste and Emergency Response, EPA 530-R-02-001.

including precious metals such as gold, silver, and palladium.  Third, many electronic products contain toxic materials that are covered by hazardous waste regulations.  Although detailed figures on waste generation are not available for PCs, EPA estimates that 916,000 tons of information products (e.g., telephones, answering machines, fax machines, modems, printers, monitors, and PCs) were generated in 2000.  Of that, only 54,960 tons were estimated to have been recycled.

The emission factors for carpet and PCs were categorized into source reduction, recycling, combustion, and landfilling.  Source reduction emissions factors were calculated as the avoided GHG emissions from the manufacture of carpet and PCs, including process energy, process non-energy, and transportation emissions. Recycling emission factors represent the GHG difference between manufacturing secondary products with recycled inputs rather than manufacturing those same products using virgin inputs.  Combustion emission factors were based on the GHG emissions from the combustion of carpet and PCs, and include offsets from energy recovery. Landfilling emission factors were based solely on transportation related emissions, since neither carpet nor PCs generate methane when disposed in a landfill.

The primary source of data used in the creation of carpet and PC emission factors was life-cycle research conducted by Franklin Associates Ltd. (FAL) for EPA in 2002.  This research provided detailed information on carpet and PC manufacturing processes, as well as related secondary product manufacturing processes.  All the information and data from FAL that was utilized in developing the GHG emission factors for carpet and PCs is included in this report via exhibits and appendixes.

Emission factors for carpet and PCs are presented in Exhibit 1 in units of metric tons of carbon equivalent per ton of product (MTCE/ton).  These emission factors are comparable to those presented in Exhibit ES-4 of the 2002 EPA report.  As in the 2002 EPA report, these emission factors do not include the "embedded energy" in plastics feedstocks.  In other words, the energy value of the feedstocks (e.g., petroleum) used to manufacture plastic was not included when estimating the energy-related GHG benefits of plastics recycling.  In terms of magnitude, source reduction of PCs is by far the most beneficial waste management practice characterized to date, largely due to the energy-intensive nature of manufacturing a PC (particularly fabrication of silicon wafers).  Source reduction of carpet falls within the range of existing values for source reduction (e.g., -2.47 MTCE/ton for aluminum cans and -0.14 MTCE/ton for glass).  In terms of recycling, both carpet and PCs have the potential for significant recycling benefits, with recycling emission factors of -1.99 MTCE/ton and -0.74 MTCE/ton, respectively.  These values fall within the range of values for other materials analyzed in the report (e.g., -4.01 MTCE/ton for aluminum cans and -0.08 MTCE/ton for glass).  Next to aluminum, the GHG savings for recycling carpet are the highest of the materials analyzed to date.

**Exhibit 1.  Carpet and PC Emission Factors (MTCE/Ton)**

| Product | Net Source Reduction Emissions For Current Mix of Inputs | Net Recycling Emissions | Net Composting Emissions | Net Combustion Emissions | Net Landfilling Emissions |
|---|---|---|---|---|---|
| Carpet | -1.11 | -1.99 | NA | 0.09 | 0.01 |
| PCs | -15.51 | -0.74 | NA | -0.06 | 0.01 |

## I. CARPET

Due to the great variability in the composition and uses of carpet, we limited our life-cycle study of GHG emissions from managing carpet waste to nylon broadloom residential carpet only. Other fibers used for carpet face fiber, such as wool or polyester, were not considered. Because the composition of commercial carpet is different than residential carpet, these emission factors only apply to broadloom residential carpet. However, we recognize that important efforts to reclaim commercial carpet are ongoing, and EPA may consider developing a commercial carpet factor at a later date, pending sufficient data. The components of nylon broadloom residential carpet in this analysis include: face fiber, primary and secondary backing, and latex used for attaching the backings. These components are briefly described below:

- The face fiber used for nylon carpet is typically made of *either* nylon 6 or nylon 6,6 (face fiber rarely includes a mix of Nylon 6 and Nylon 6,6). However, for the purpose of developing an emission factor that represents "typical" nylon broadloom residential carpet, our analysis reflects the market share of each material in the nylon carpet industry (45 percent Nylon 6 and 55 percent Nylon 6,6).
- Carpet backing for broadloom carpet typically consists of polypropylene. Inputs to the manufacture of polypropylene are crude oil and/or natural gas.
- For latex used to adhere carpet backings, we modeled styrene butadiene, the most common latex used for this purpose. Styrene butadiene latex is commonly compounded with a filler such as calcium carbonate (limestone).

Specifically, one ton of virgin carpet was assumed to consist of: 410 pounds of virgin Nylon 6 resin; 500 pounds of Nylon 6,6 resin; 304 pounds of woven polypropylene backing; 164 pounds of SB latex; and 648 pounds of limestone used as filler in the latex adhesive.[4]

The process used to turn these components into a finished carpet may include weaving, tufting, needlepunching, and/or knitting. According to the Carpet and Rug Institute, 90 percent of carpet produced in the United States is tufted. During tufting, face pile yarns are rapidly sewn into a primary backing by a wide multi-needled machine. After the face pile yarns are sewn into the primary backing, a layer of latex is used to secure a secondary backing, which adds strength and dimensional stability to the carpet.

Although most waste carpet is disposed, roughly 3.6 percent of carpet is recovered for recycling. Unlike most of the other materials analyzed by EPA to date, carpet is not recycled into more carpet, but rather into one of three secondary products: carpet pad, molded products, and carpet backing.

The following sections describe how we used information on carpet and end uses for recycled carpet to develop life-cycle GHG emission factors for source reduction, recycling, combustion, and landfilling.

### Source Reduction

Source reduction activities reduce the amount of carpet that needs to be produced, and consequently, reduce GHG emissions associated with carpet production. Source reduction of carpet can be achieved through using less carpeting material per square foot (i.e., thinner carpet), or by finding a way to make existing carpet last longer through cleaning or repair.

The GHG benefits of source reduction are calculated as the avoided emissions from the raw materials acquisition and manufacture of carpet. The energy used in these processes is primarily fossil fuel derived, resulting in GHG emissions. In addition, energy is required to obtain the fuels used in carpet manufacturing. The calculation of avoided GHG emissions for carpet was broken up into three components: process energy,

[4] Note that these values total 2,026 pounds, which is greater than one ton. This is because 26 pounds of the raw materials used to manufacture carpet are assumed to be "lost" during the manufacturing process. In other words, producing one ton of carpet actually requires slightly greater than one ton of raw materials.

transportation energy, and non-energy emissions.[5] Exhibit 2 presents these results, as well as the net GHG emission factor for source reduction. Appendix A presents the raw data utilized in these calculations.

**Exhibit 2. Carpet Source Reduction Emission Factor (MTCE/Ton)**

| (a) Process Energy | (b) Transportation Energy | (c) Process Non-Energy | (d) Net Emissions (=a + b + c) |
|---|---|---|---|
| -0.94 | -0.03 | -0.14 | -1.11 |

<u>Avoided Process Energy</u>

In carpet manufacturing, energy is required to obtain raw materials and to operate carpet manufacturing equipment, as well as to extract and refine the fuels used in the carpet manufacturing process (i.e., "pre-combustion" energy). Process energy GHG emissions result from both the direct combustion of fossil fuels and the upstream emissions associated with electricity use. To estimate process emissions, we first obtained an estimate of the total energy required to produce one ton of carpet, which is reported as 60.32 million Btu.[6] Next, we determined the distribution of fuels that comprise this Btu estimate. Using this information, we then multiplied each fuel's Btu estimate by each fuel's carbon content to obtain carbon dioxide ($CO_2$) emissions for each fuel. The carbon coefficients we used are presented in Exhibit 3. We then conducted a similar analysis for fugitive methane ($CH_4$) emissions, using fuel-specific $CH_4$ coefficients. Finally, total process energy GHG emissions were calculated as the sum of GHG emissions, including both $CO_2$ and $CH_4$, from all the fuel types used in the production of one ton of carpet. The calculations for process energy emissions from manufacturing carpet are provided in Exhibit 3. As the exhibit shows, the process energy for carpet results in 0.94 MTCE per ton of carpet produced.

[5] While carpet contains petrochemically-derived components, this report does not consider the carbon stored in these components since they do not result in actual carbon emissions. In addition, even though these components *store* carbon, they do not *remove* carbon from the atmosphere, and therefore are not considered a "carbon sink." EPA does consider embodied energy, however, in the energy savings calculations of the WAste Reduction Model (WARM).

[6] This total represents the sum of pre-combustion and combustion process energy.

**Exhibit 3. Process Energy Emissions Calculations**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Carpet Production (=60.32[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.4741 | 0.2860 | 0.0192 | 0.0001 | 0.0055 | 0.0000 | 0.0055 |
| LPG | 0.0368 | 0.0222 | 0.0169 | 0.0001 | 0.0004 | 0.0000 | 0.0004 |
| Distillate Fuel | 0.6698 | 0.4040 | 0.0199 | 0.0001 | 0.0080 | 0.0000 | 0.0081 |
| Residual Fuel | 1.4821 | 0.8940 | 0.0214 | 0.0001 | 0.0191 | 0.0001 | 0.0192 |
| Diesel | 0.0000 | 0.0000 | 0.0199 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| National Average Fuel Mix for Electricity | 52.0555 | 31.3999 | 0.0158 | 0.0006 | 0.4959 | 0.0185 | 0.5145 |
| Coal Used by Industry (Non-Coking Coal) | 0.8190 | 0.4940 | 0.0251 | 0.0009 | 0.0124 | 0.0005 | 0.0129 |
| Natural Gas | 44.0980 | 26.5999 | 0.0138 | 0.0007 | 0.3666 | 0.0186 | 0.3852 |
| Nuclear | 0.2785 | 0.1680 | 0.0008 | 0.0000 | 0.0001 | 0.0000 | 0.0001 |
| **Total** | 100 | 60.32 | n/a | n/a | 0.90 | 0.04 | **0.94** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix A.
b. Source: Franklin Associates, Ltd., 2002a. *Energy and Greenhouse Gas Factors for Nylon Broadloom Residential Carpet,* July 3, 2002.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: U. S. Department of Energy, EIA, 2001. *Annual Energy Review: 2000*. August.

## Transportation Energy

Transportation energy GHG emissions result from the combustion of fossil fuels to transport carpet raw materials and intermediate products.[7] The methodology for estimating transportation energy GHG emissions is similar to the methodology for process emissions. Based upon an estimate of total carpet transportation energy and the corresponding fuel mix, we calculated total transportation energy emissions using fuel-specific coefficients for $CO_2$ and $CH_4$. The result is a transportation GHG emission factor of 0.03 MTCE per ton of carpet, as shown in Exhibit 4.

[7] Note: As with other materials for which we have developed GHG emission factors, transportation of finished goods to consumers was not included in the analysis.

**Exhibit 4. Transportation Energy Emissions Calculations**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Carpet Transport (=1.36[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu)[c] | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1466 | 0.0020 | 0.0192 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| LPG | 0.0733 | 0.0010 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.3957 | 0.0054 | 0.0199 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Residual Fuel | 28.6108 | 0.3891 | 0.0214 | 0.0001 | 0.0083 | 0.0000 | 0.0084 |
| Diesel | 51.8864 | 0.7057 | 0.0199 | 0.0001 | 0.0140 | 0.0001 | 0.0141 |
| National Average Fuel Mix for Electricity | 1.7589 | 0.0239 | 0.0158 | 0.0006 | 0.0004 | 0.0000 | 0.0004 |
| Coal Used by Industry (Non-Coking Coal) | 0.8794 | 0.0120 | 0.0251 | 0.0009 | 0.0003 | 0.0000 | 0.0003 |
| Natural Gas | 15.8297 | 0.2153 | 0.0138 | 0.0007 | 0.0030 | 0.0002 | 0.0031 |
| Nuclear | 0.3225 | 0.0044 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 1.36 | n/a | n/a | 0.03 | 0.0003 | **0.03** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix A.
b. Source: FAL 2002a.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

Process Non-energy Emissions

In addition to emissions associated with combustion, manufacturing results in non-energy GHG emissions. Non-energy GHG emissions occur during manufacturing but are not the result of combusting fuel for energy; rather, they occur from activities such as the use of solvents or chemical treatments. Data on non-energy process emissions were provided by FAL for $CO_2$, $CH_4$, and nitrous oxide ($N_2O$), in units of pounds of native gas per 1,000 pounds of carpet. These estimates were multiplied by a factor of two to convert from pounds per 1,000 pounds to pounds per short ton, and then converted to metric tons of gas per short ton. Next, the estimates were converted from metric tons of native gas to MTCE by multiplying by the MTCE per metric ton of gas. These calculations are shown in Exhibit 5.

**Exhibit 5. Process Non-energy Emissions**

| Gas | (a) Lbs of Gas per 1,000 Lbs of Carpet | (b) Lbs of Gas per Ton of Carpet (=a x 2) | (c) Metric Tons of Gas per Ton of Carpet (=b / 2205 Metric Tons per Pound) | (d) MTCE/Metric Ton of Gas | (e) MTCE/Ton of Carpet (=c x d) |
|---|---|---|---|---|---|
| $CO_2$ | 9.71 | 19.42 | .0088 | 0.27 | 0.0024 |
| $CH_4$ | 2.72 | 5.44 | .0025 | 5.73 | 0.0141 |
| $N_2O$ | 1.6 | 3.2 | .0015 | 84.55 | 0.1227 |
| **Total** | NA | n/a | n/a | n/a | **0.1392** |

Note: Totals may not sum due to independent rounding.

Finally, it should be noted that for most materials, a portion of the material in new production is recycled product (e.g., aluminum can production typically utilizes some recycled aluminum). For this reason, we have developed two source reduction emission factors – "current mix" and "100 percent virgin" – for all materials analyzed in the 2002 EPA report. The current mix emission factor is more conservative, assuming that source reduction displaces the current mixture of virgin/recycled product. However, since carpet is currently produced using 100 percent virgin materials, the two emission factors for carpet are identical – both assume that carpet source reduction displaces 100 percent virgin materials.

The final source reduction emission factor, -1.11 MTCE/ton, was calculated by simply summing the avoided process energy emissions, transportation energy emissions, and process non-energy emissions as given in Exhibits 3 through 5.

**Recycling**

According to EPA, 3.6 percent of carpet is recycled annually.[8] New efforts by industry, EPA, and other organizations are expected to significantly increase the fraction of waste carpet that is recycled. EPA hopes that the GHG emission factor for carpet can be used to characterize the benefits of these increased recycling efforts.

Unlike most of the materials for which EPA has developed GHG emission factors (e.g., aluminum cans, glass bottles), carpet is assumed to be recycled in an "open loop" – i.e., carpet is recycled into new products other than new carpet. Therefore, the GHG benefits of carpet recycling result from the avoided emissions associated with the manufacture of the *secondary* products that carpet is recycled into (since the recycling would only affect the production of the secondary products). Secondary products resulting from carpet recycling include: carpet pad, molded products, and carpet backing. Carpet pad is used as a cushion layer between the carpet and the floor that provides thermal and acoustical insulation, and resilience. Molded products for automobiles are used in a wide range of applications, from air intake assemblies to headrests. The carpet backing produced from recycled carpet is generally used to secure the yarn and provide dimensional stability to commercial carpeting. For one carpet recycling company, this carpet backing contains a minimum of 31 percent recycled material. An advantage to recycling carpet into backing is that it uses 100 percent of the materials from the recovered carpet, thereby avoiding a solid waste stream from the recycling process. The percentage of recycled carpet that each of these secondary products comprises is shown in Exhibit 6.

To calculate the GHG benefits of recycling carpet, we compared the difference in emissions associated with manufacturing a ton of each of the secondary products from virgin versus recycled materials, after accounting for losses that occur in the recycling process. The results for each of the secondary products were then weighted by the distribution shown in Exhibit 6 to obtain a composite emission factor for recycling a ton of carpet. In applying this method, we only considered the GHG benefit for one generation of recycling (i.e., we did not include future benefits from recycling the secondary products into additional products).

[8] EPA 2002.

Note that the emissions reductions from recycling are independent of the reductions from source reducing carpet. That is, our calculations assume that the current mix of residential broadloom carpet is recycled and does not assume that source reduced (i.e., thinner) carpet is being recycled.

Similar to source reduction, the calculation of avoided GHG emissions for carpet was broken up into three components: process energy, transportation energy, and non-energy emissions. Exhibit 7 displays these results for all three secondary products after being weighted by the percentages in Exhibit 6; these results are followed by the total GHG emission factor for recycling. Appendix B presents the raw data utilized in these calculations.

**Exhibit 6. Fate of Recycled Carpet: Secondary Products and Percent Composition**

| Secondary Product | Percent Composition |
|---|---|
| Carpet Pad/Cushion | 67 |
| Molded Products (auto parts) | 25 |
| Backing for Commercial Carpet Tiles | 8 |

**Exhibit 7. Carpet Recycling Emission Factor (MTCE/Ton)**

| (a) Process Energy | (b) Transportation Energy | (c) Process Non-Energy | (d) Net Emission Factor (=a + b + c) |
|---|---|---|---|
| -1.5 | -0.02 | -0.47 | -1.99 |

To calculate each component of the recycling emission factor for the secondary products, the following steps were necessary:

Step 1: Calculate the emissions for virgin production of one ton of the secondary product for each emission factor component (e.g., the process energy emissions for virgin production of carpet pad/cushion).

Step 2: Calculate the equivalent emissions for recycled production of one ton of the secondary product.

Step 3. Calculate the difference in emissions between virgin and recycled production.

Step 4. Adjust the difference in emissions to account for recycling losses.

Step 5: Weight the results by the percentage of recycled carpet that the secondary material comprises.

These steps are described in more detail below, with illustrative exhibits provided for "Molded Products (auto parts)" (hereafter called "molded auto parts"). Similar calculations were used for the other secondary products.

Step 1. Calculate the emissions for virgin production of one ton of the secondary product. Since the GHG benefits of recycling are calculated as difference in emissions between virgin and recycled production, we first calculated emissions for virgin production.[9] As described in the section on source reduction, both process and transportation energy emissions are calculated by applying fuel-specific emissions coefficients to energy data for raw materials acquisition and manufacturing. The calculations for virgin process and transportation emissions for molded auto parts are shown in Exhibits 8 and 9, respectively. Exhibit 10 presents the estimates of process non-energy data for virgin molded auto parts.

[9] Note that emissions reductions for source reduction are calculated for both 100 percent virgin and the "current mix" of virgin/recycled inputs. It is assumed that incremental increases in recycling offset only virgin production, and consequently, we do not provide "current mix" recycling emission factors.

**Exhibit 8. Molded Auto Parts – Process Energy Emissions Calculations for Virgin Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Molded Auto Parts (=113.75[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu)[c] | (d) Fugitive $CH_4$ Emissions MTCE/Million Btu[c] | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.4009 | 0.4560 | 0.0192 | 0.0001 | 0.0088 | 0.0000 | 0.0088 |
| LPG | 0.0190 | 0.0216 | 0.0169 | 0.0001 | 0.0004 | 0.0000 | 0.0004 |
| Distillate Fuel | 0.6752 | 0.7680 | 0.0199 | 0.0001 | 0.0153 | 0.0001 | 0.0153 |
| Residual Fuel | 1.1253 | 1.2800 | 0.0214 | 0.0001 | 0.0274 | 0.0001 | 0.0275 |
| Diesel | 0.0000 | 0.0000 | 0.0199 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| National Average Fuel Mix for Electricity | 61.1881 | 69.6015 | 0.0158 | 0.0006 | 1.0993 | 0.0411 | 1.1404 |
| Coal Used by Industry (Non-Coking Coal) | 0.7912 | 0.9000 | 0.0251 | 0.0009 | 0.0226 | 0.0008 | 0.0234 |
| Natural Gas | 35.4117 | 40.2808 | 0.0138 | 0.0007 | 0.5551 | 0.0282 | 0.5833 |
| Nuclear | 0.2989 | 0.3400 | 0.0008 | 0.0000 | 0.0003 | 0.0000 | 0.0003 |
| **Total** | 100 | 113.75 | n/a | n/a | 1.73 | 0.07 | **1.79** |

Note: Totals may not sum due to independent rounding.

a. Calculated using fuel-specific Btu data provided in Appendix B.

b. Source: FAL 2002a.

c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 9. Molded Auto Parts – Transportation Energy Emissions Calculations for Virgin Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Molded Auto Parts Transport (=1.51[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1587 | 0.0024 | 0.0192 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| LPG | 0.0661 | 0.0010 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.3836 | 0.0058 | 0.0199 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Residual Fuel | 43.1527 | 0.6516 | 0.0214 | 0.0001 | 0.0140 | 0.0001 | 0.0140 |
| Diesel | 35.1889 | 0.5314 | 0.0199 | 0.0001 | 0.0106 | 0.0001 | 0.0106 |
| National Average Fuel Mix for Electricity | 2.5135 | 0.0380 | 0.0158 | 0.0006 | 0.0006 | 0.0000 | 0.0006 |
| Coal Used by Industry (Non-Coking Coal) | 0.8070 | 0.0122 | 0.0251 | 0.0009 | 0.0003 | 0.0000 | 0.0003 |
| Natural Gas | 17.3299 | 0.2617 | 0.0138 | 0.0007 | 0.0036 | 0.0002 | 0.0038 |
| Nuclear | 0.3043 | 0.0046 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 1.51 | n/a | n/a | 0.03 | 0.0003 | **0.03** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix B.
b. Source: FAL 2002a.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 10. Molded Auto Parts – Process Non-energy Emissions for Virgin Materials**

| Gas | (a) Lbs of Gas per 1,000 Lbs of Molded Auto Parts | (b) Lbs of Gas per Ton of Molded Auto Parts (=a x 2) | (c) Metric Tons of Gas per Ton of Molded Auto Parts (=b / 2205 Metric Tons per Pound) | (d) MTCE/Metric Ton of Gas | (e) MTCE/Ton of Molded Auto Parts (=c x d) |
|---|---|---|---|---|---|
| $CO_2$ | 17 | 34 | 0.0154 | 0.27 | 0.0042 |
| $CH_4$ | 3.76 | 7.52 | 0.0034 | 5.73 | 0.0195 |
| $N_2O$ | 6.42 | 12.84 | 0.0058 | 84.55 | 0.4923 |
| **Total** | NA | n/a | n/a | n/a | **0.52** |

Note: Totals may not sum due to independent rounding.

<u>Step 2. Calculate the emissions for recycled production of one ton of the secondary product</u>. After estimating emissions from virgin production of secondary products, we then conducted a similar analysis for recycled production. Exhibits 11 and 12 show the results for process energy emissions and transportation emissions for molded auto parts, respectively. There are no reported non-energy emissions from the production of molded auto parts from recycled carpet.

**Exhibit 11. Molded Auto Parts – Process Energy Emissions Calculations for Recycled Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Molded Auto Parts (=20.24[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1186 | 0.0240 | 0.0192 | 0.0001 | 0.0005 | 0.0000 | 0.0005 |
| LPG | 0.0034 | 0.0007 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.6818 | 0.1380 | 0.0199 | 0.0001 | 0.0027 | 0.0000 | 0.0028 |
| Residual Fuel | 0.2569 | 0.0520 | 0.0214 | 0.0001 | 0.0011 | 0.0000 | 0.0011 |
| Diesel | 0.0000 | 0.0000 | 0.0199 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| National Average Fuel Mix for Electricity | 95.4513 | 19.3194 | 0.0158 | 0.0006 | 0.3051 | 0.0114 | 0.3165 |
| Coal Used by Industry (Non-Coking Coal) | 0.9486 | 0.1920 | 0.0251 | 0.0009 | 0.0048 | 0.0002 | 0.0050 |
| Natural Gas | 2.0750 | 0.4200 | 0.0138 | 0.0007 | 0.0058 | 0.0003 | 0.0061 |
| Nuclear | 0.3557 | 0.0720 | 0.0008 | 0.0000 | 0.0001 | 0.0000 | 0.0001 |
| **Total** | 100 | 20.24 | n/a | n/a | 0.32 | 0.01 | **0.33** |

Note: Totals may not sum due to independent rounding.

a. Calculated using fuel-specific Btu data provided in Appendix B.

b. Source: FAL 2002a.

c. Source The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 12. Molded Auto Parts – Transportation Energy Emissions Calculations for Recycled Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Molded Auto Parts Transport (=1.05[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1012 | 0.0011 | 0.0192 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| LPG | 0.0783 | 0.0008 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.3819 | 0.0040 | 0.0199 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Residual Fuel | 3.8192 | 0.0401 | 0.0214 | 0.0001 | 0.0009 | 0.0000 | 0.0009 |
| Diesel | 87.8416 | 0.9223 | 0.0199 | 0.0001 | 0.0183 | 0.0001 | 0.0184 |
| National Average Fuel Mix for Electricity | 0.0000 | 0.0000 | 0.0158 | 0.0006 | 0.0000 | 0.0000 | 0.0000 |
| Coal Used by Industry (Non-Coking Coal) | 0.8593 | 0.0090 | 0.0251 | 0.0009 | 0.0002 | 0.0000 | 0.0002 |
| Natural Gas | 6.4926 | 0.0682 | 0.0138 | 0.0007 | 0.0009 | 0.0000 | 0.0010 |
| Nuclear | 0.3246 | 0.0034 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 1.05 | n/a | n/a | 0.02 | 0.0002 | **0.02** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix B.
b. Source: FAL 2002a.
c. Source: The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

Step 3. Calculate the difference in emissions between virgin and recycled production. The GHG savings associated with recycling were then calculated by subtracting the recycled emissions estimate from the virgin emissions estimate using the results from Steps 1 and 2. The results are shown in Exhibit 13.

**Exhibit 13. Emission Difference Between Virgin and Recycled Molded Auto Parts Manufacture (MTCE/Ton)**

| | Process Energy Emissions | Transportation Energy Emissions | Process Non-energy Emissions |
|---|---|---|---|
| Virgin Manufacture | 1.79 | 0.03 | 0.52 |
| Recycled Manufacture | 0.33 | 0.02 | 0.00 |
| **Difference** | **1.46** | **0.01** | **0.52** |

Note: Totals may not sum due to rounding.

Step 4. Adjust the emissions differences to account for recycling losses. For almost every material that gets recycled, some portion of the recovered material is unsuitable for use as a recycled input. This portion is discarded either in the recovery stage or in the manufacturing stage. Consequently, less than one ton of new material is typically made from one ton of recovered materials. Material losses are quantified and translated into loss rates. In the case of carpet, no data were available on recovery-stage losses, so we assumed no losses during this stage. For the recycling stage, data indicated a loss rate for molded auto parts of 0.5 percent. Zero loss rates were reported for the other two secondary products (carpet pad and backing for commercial carpet tiles).

In order to account for the fact that not all of the carpet recovered for use as molded auto parts was actually used for this purpose, it was necessary to multiply the emissions differences from Step 3 for each of the emissions components by the recycling "retention" rate (i.e., 1 – the loss rate). Exhibit 14 shows this calculation for molded auto parts.

**Exhibit 14. Calculation of Adjusted GHG Savings for Carpet Recycled into Molded Auto Parts**

| | (a)<br>Virgin Production (MTCE/Ton) | (b)<br>Recycled Production (MTCE/Ton) | (c)<br>Unadjusted GHG Savings (MTCE/Ton) (=a - b) | (d)<br>Recycling Retention Rate (=1-0.005) | (e)<br>Adjusted GHG Savings (MTCE/Ton) (=c x d) |
|---|---|---|---|---|---|
| Process Energy | 1.79 | 0.33 | 1.46 | 0.995 | 1.45 |
| Transportation Energy | 0.03 | 0.02 | 0.01 | 0.995 | 0.01 |
| Process Non-energy | 0.52 | 0 | 0.52 | 0.995 | 0.51 |

Note: Totals may not sum due to rounding.

Step 5. Weight the results by the percentage of recycled carpet that the secondary material comprises. Once the individual GHG differences are calculated for each of the secondary products, the final step is to weight the differences by their relative percentages, as provided in Exhibit 6. In the case of molded auto parts, the MTCE/ton estimates from step 4 were weighted by the percentage of recycled carpet converted to molded auto parts (25 percent), as shown below:

Process Energy: 1.45 $\text{MTCE/ton}_{\text{unweighted}}$ x 25 % = 0.36 MTCE/ton

Transportation Energy: 0.01 $\text{MTCE/ton}_{\text{unweighted}}$ x 25 % = 0.002 MTCE/ton

Process Non-energy: 0.51 $\text{MTCE/ton}_{\text{unweighted}}$ x 25 % = 0.13 MTCE/ton

The weighted results for all three secondary materials are shown in Exhibit 15.

**Exhibit 15. Carpet Recycling Emission Factor (MTCE/Ton)**

| | (a)<br>Process Energy | (b)<br>Transportation Energy | (c)<br>Process Non-Energy | (d)<br>Total (=a + b + c) |
|---|---|---|---|---|
| Carpet Pad/Cushion | (1.1) | (0.01) | (0.34) | **(1.46)** |
| Molded Products (auto parts) | (0.36) | (0.002) | (0.13) | **(0.49)** |
| Backing for Commercial Carpet Tiles | (0.03) | (0.0004) | (0.003) | **(0.03)** |
| **Net Emissions** | **(1.5)** | **(0.02)** | **(0.47)** | **(1.99)** |

Note: Results for molded auto parts, derived in Exhibits 8 through 14, are shaded above.

**Combustion**

Currently, 19 percent of carpet in the national municipal solid waste stream is combusted. Combustion results in both direct and indirect emissions: direct emissions from the combustion process itself and indirect emissions associated with transportation to the combustor. To the extent that carpet combusted at waste-to-energy (WTE) facilities produces electricity, combustion offsets $CO_2$ emissions from electric utilities.

According to guidelines published by the Intergovernmental Panel on Climate Change (IPCC), emissions of $CO_2$ from biogenic sources are not included in GHG accounting because these emissions are assumed to be part of the natural carbon cycle.[10] However, we estimated that 53 percent of carpet is non-biogenic and that 98 percent of the non-biogenic carbon is converted to $CO_2$ during combustion.[11] Direct $CO_2$ emissions from combustion of carpet were estimated at 0.47 MTCE per ton of carpet. Exhibit 16 shows how we calculate this estimate.

**Exhibit 16. Carpet Combustion Emissions Factor Calculation**

| **Components** | **(a)** **Percent of Total Weight of Combusted Carpet** | **(b)** **Percent Non-Biomass Carbon Content** | **(c)** **Non-Biomass Carbon Content % of Total Weight (=a x b)** | **(d)** **Factored by % Carbon to $CO_2$ (=c x 0.98)** | **(e)** **MTCE per Ton of Carpet (=d / 1.1023)** |
|---|---|---|---|---|---|
| Styrene-butadiene (latex) | 8 | 90 | 7 | 7 | 0.06 |
| Limestone | 32 | 12 | 4 | 4 | 0.03 |
| Polypropylene | 15 | 86 | 13 | 13 | 0.11 |
| Nylon | 45 | 64 | 29 | 28 | 0.26 |
| **Total** | | | 53 | | **0.47** |

As with other materials covered in EPA's *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks*, we estimated $CO_2$ emissions from the transportation of carpet to WTE plants and ash from the WTE plant to the landfill using data provided by FAL. Transportation-related $CO_2$ emissions were estimated to be 0.01 MTCE.

Because most utility power plants use fossil fuels to produce electricity, the electricity produced at WTE facilities reduces the demand for fossil-derived electricity and the associated $CO_2$ emissions. Avoided utility $CO_2$ emissions were calculated based on the energy content of the carpet, the combustion efficiency of the WTE plant including transmission and distribution losses, and the $CO_2$ emissions avoided by the power plant on a per kilowatt-hour (kwh) basis. The estimate of emissions avoided per kwh reflects the national average mix of fuel sources and the resulting $CO_2$ emissions. Carpet combustion was estimated to result in utility offsets of 0.39 MTCE per ton, as shown in Exhibit 17.

**Exhibit 17. Utility Emissions Offset From Carpet Combustion**

| **(a)** **Energy Content (Btu Per Pound)** | **(b)** **Energy Content (Million Btu Per Ton) (=a x 0.002[a])** | **(c)** **Mass Burn Combustion System Efficiency (Percent)** | **(d)** **Emission Factor for Utility-Generated Electricity (MTCE/ Million Btu of Electricity Delivered)** | **(e)** **Avoided Utility $CO_2$ Per Ton Combusted at Mass Burn Facilities (MTCE) (=b x c x d)** |
|---|---|---|---|---|
| 13,400 | 26.8 | 0.18 | 0.08 | 0.39 |

a. Source: FAL 2002a.

[10] See page 12 of EPA's *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks.*

[11] This calculation is based upon the percent composition of non-biogenic latex, limestone, polypropylene, and nylon components of carpet.

As shown in Exhibit 18, the net combustion emission factor for carpet is equal to the sum of the carpet combustion $CO_2$ emissions and transportation emissions, minus the utility offset, or 0.09 MTCE per ton.

**Exhibit 18. Carpet Combustion Emission Factor (MTCE/Ton)**

| (a)<br>Combustion Emissions | (b)<br>Transportation Energy | (c)<br>Avoided Utility Emissions | (d)<br>Net Combustion Emissions (=a + b - c) |
|---|---|---|---|
| 0.47 | 0.01 | 0.39 | 0.09 |

**Landfilling**

Roughly 77 percent of carpet is landfilled after entering the municipal solid waste stream, making landfilling the most commonly-selected waste management option for carpet. Typically, the emission factor for landfilling is comprised of four parts: landfill $CH_4$, $CO_2$ emissions from transportation and landfill equipment, landfill carbon storage, and avoided utility emissions. However, as with other inorganic materials for which EPA has developed emission factors, there are zero landfill methane emissions, landfill carbon storage, or avoided utility emissions associated with landfilling carpet. As a result, the emission factor for landfilling represents the $CO_2$ emissions associated with combusting diesel fuel to collect the waste and operate the landfill equipment. These emissions were estimated at 0.01 MTCE per ton of carpet landfilled.[12]

## II. PERSONAL COMPUTERS

This section presents the methodology used to estimate the life-cycle GHG impacts of end-of-life waste management options for PCs. The main components of a PC are the central processing unit (CPU) and the monitor. The CPU consists of housing (mostly steel) and internal electronic components, while the monitor's primary components are the cathode ray tube (CRT), plastic case, and circuit boards.

Due to the heterogeneity of PCs, it is difficult to specify the exact composition of a typical PC. Some characterizations of PCs include monitors and peripheral equipment (e.g., keyboards, external cables, printers), while others exclude these components. For this study, we considered both the CPU and monitor, but did not include peripherals. In addition, this study represents a "snapshot" of a typical PC at the time this report was published. Since PC technology continues to evolve rapidly (e.g., replacement of traditional PC monitors with thinner "flat screen" monitors), the assumptions regarding material composition of PCs may be revisited in future years. Likewise, the fate of recycled PC materials (e.g., plastics into asphalt) may also be affected by technological changes in recycling processes. The material composition of a desktop PC is provided in Exhibit 19. Summary information on each of the PC components is provided below.

[12] Landfill data obtained from Franklin Associates, Ltd., 1994. *The Role of Recycling in Integrated Solid Waste Management for the Year 2000* (Stamford, CT: Keep America Beautiful, Inc.) September, p. I-5.

**Exhibit 19. Material Composition of a Desktop Personal Computer (CPU and Monitor)**

| Material | Application(s) | Percent of Total Weight | Weight (lbs) (Assuming a 70 lb computer) |
|---|---|---|---|
| Plastics | | | |
| ABS | Monitor case and other molded parts | 8.0 | 5.6 |
| PPO/HIPS | | 5.3 | 3.7 |
| TBBPA (flame retardant) | | 5.7 | 4.0 |
| Glass | CRT glass/ Substrate for PWBs | 22.0 | 15.4 |
| Lead | CRT glass / Electronic connections | 8.0 | 5.6 |
| Steel | CPU case / CRT shield | 28.6 | 20.0 |
| Copper | PWB conductor / wiring | 6.6 | 4.6 |
| Zinc | Galvanization of CPU case | 3.0 | 2.1 |
| Aluminum | Structural components/ PWB conductor | 9.5 | 6.7 |
| Other | Metals and plastics for disk drives, fasteners, and power supplies. | 3.3 | 2.3 |
| **Total** | | 100 | **70 lbs** |

The number of components that comprise a PC and the complexity associated with manufacturing the various components required that we focus our efforts on the key materials and processes of PC production. In particular, the life-cycle analysis of PC production includes the following steps:

- *Chip manufacture (including wafer production, fabrication, and packaging)*. A chip (or integrated circuit) is a compact device made of a semi-conducting material such as silicon. Chip manufacture requires thousands of steps, but the primary steps are wafer production, wafer fabrication, and chip packaging.
- *Printed wiring board production*. Printed wiring boards (PWBs) are part of the circuitry in electronic products.
- *CRT production*. Computer monitors and televisions are the two largest applications for CRTs. A CRT is made of many materials and sub-assemblies, including a glass funnel, glass neck, faceplate (screen), electron gun, shadow mask, phosphors, and PWBs.
- *Monitor housing production*. The monitor case is made of one or more types of plastic resin including acrylonitrile-butadiene-styrene (ABS), polyphenylene ether alloys (referred to as PPE or PPO), and high impact polystyrene (HIPS). Monitor production also involves incorporation of flame retardants into the monitor housing.
- *CPU housing production*. CPU cases are made of plastic panels and face plates and steel for structural stability. Much of the steel used in CPU cases is scrap steel, the rest is manufactured from virgin inputs.
- *PC assembly*. PCs are assembled manually, and the main energy requirement is the operation of conveyor belts for the assembly line.

As with carpet, PCs are not recycled into more PCs; therefore, the life-cycle analysis of GHG emissions associated with their disposal must take into account the various second generation products that result from recycling PCs. Data on PC recycling and the resulting second generation products is very sparse; however, we attempted to model the most likely pathways for recycled components of PCs using data provided by FAL. The second generation products included in this analysis include: glass cullet, lead bullion, scrap steel, scrap copper, scrap aluminum, and ground plastic as an input to asphalt manufacture.

The following sections describe how we used information on the individual components of PCs and information on the second generation products associated with recycling PCs to develop life-cycle GHG emission factors for source reduction, recycling, combustion, and landfilling.

**Source Reduction**

Source reduction activities reduce the amount of PCs that are produced, thereby reducing GHG emissions from PC production. Source reduction of PCs can be achieved through finding ways to make existing PCs last longer (e.g., through upgrades and using interchangeable parts), or by finding other alternatives to purchasing new PCs (e.g., using donated PCs).

The GHG benefits of source reduction are calculated as the avoided emissions from the raw materials acquisition and manufacture of PCs. In the case of PCs, these emissions are substantial, since PC manufacture (and in particular, silicon wafer production) is an energy-intensive process.

As was done for carpet, the calculation of avoided GHG emissions for PCs was broken up into three components: process energy, transportation energy, and non-energy emissions. Exhibit 20 displays these results, as well as the total GHG emission factor for source reduction. Appendix C presents the raw data utilized in these calculations.

**Exhibit 20. Personal Computer Source Reduction Emission Factor (MTCE/Ton)**

| (a) Process Energy | (b) Transportation Energy | (c) Process Non-Energy | (d) Net Emissions (=a + b + c) |
|---|---|---|---|
| -15.38 | -0.10 | -0.03 | -15.51 |

<u>Avoided Process Emissions</u>

The procedure for estimating process energy GHG emissions for PCs is the same as the procedure used for carpet. We first obtained an estimate of the amount of energy to produce one ton of PCs, which is reported as 945 million Btu. Next, we determined the fuel mix that comprised this Btu estimate. We then multiplied fuel consumption (in Btus) by fuel-specific carbon contents to obtain GHG emissions by fuel type. The total process energy GHG emissions were calculated as the sum of the GHG emissions, including $CO_2$ and $CH_4$, from all the fuel types used in the production of one ton of PCs. The calculations for the process energy used to produce PCs are presented in Exhibit 21. As the exhibit shows, the process energy for PCs is 15.51 MTCE per ton of PCs produced.

**Exhibit 21. Process Energy Emissions Calculations**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for PC Production (=945.13[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu [c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1365 | 1.2900 | 0.0192 | 0.0001 | 0.0248 | 0.0001 | 0.0250 |
| LPG | 0.0039 | 0.0368 | 0.0169 | 0.0001 | 0.0006 | 0.0000 | 0.0006 |
| Distillate Fuel | 0.7215 | 6.8191 | 0.0199 | 0.0001 | 0.1355 | 0.0007 | 0.1362 |
| Residual Fuel | 0.3774 | 3.5668 | 0.0214 | 0.0001 | 0.0764 | 0.0003 | 0.0767 |
| Diesel | 0.1038 | 0.9808 | 0.0199 | 0.0001 | 0.0195 | 0.0001 | 0.0196 |
| National Average Fuel Mix for Electricity | 92.4191 | 873.4792 | 0.0158 | 0.0006 | 13.7958 | 0.5119 | 14.3077 |
| Coal Used by Industry (Non-Coking Coal) | 0.9671 | 9.1400 | 0.0251 | 0.0009 | 0.2294 | 0.0084 | 0.2379 |
| Natural Gas | 4.9976 | 47.2340 | 0.0138 | 0.0007 | 0.6509 | 0.0331 | 0.6841 |
| Nuclear | 0.3503 | 3.3109 | 0.0008 | 0.0000 | 0.0028 | 0.0000 | 0.0028 |
| **Total** | 100 | 945.13 | n/a | n/a | 14.96 | 0.56 | **15.38** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix C.
b. Source: Franklin Associates, Ltd., 2002b. *Energy and Greenhouse Gas Factors for Personal Computers – Final Report,* August 7, 2002.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

## Transportation Energy

Transportation energy GHG emissions consist of fossil fuels used to transport PC raw materials and intermediate products.[13] The methodology for estimating transportation energy GHG emissions is similar to that for process emissions. Based upon an estimate of total PC transportation energy in Btus, we calculated the total transportation energy emissions using fuel-specific carbon coefficients for $CO_2$ and $CH_4$. The result is a transportation GHG emission factor of 0.1 MTCE per ton of PCs, as shown in Exhibit 22.

[13] Note: As with other materials for which we have developed GHG emission factors, transportation of finished goods to consumers was not included in the analysis.

**Exhibit 22. Transportation Energy Emissions Calculations**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for PC Transport (=5.03 x a)[b] | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1027 | 0.0052 | 0.0192 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| LPG | 0.0781 | 0.0039 | 0.0169 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Distillate Fuel | 0.4110 | 0.0207 | 0.0199 | 0.0001 | 0.0004 | 0.0000 | 0.0004 |
| Residual Fuel | 60.2205 | 3.0291 | 0.0214 | 0.0001 | 0.0649 | 0.0003 | 0.0652 |
| Diesel | 30.6446 | 1.5414 | 0.0199 | 0.0001 | 0.0306 | 0.0002 | 0.0308 |
| National Average Fuel Mix for Electricity | 0.2873 | 0.0145 | 0.0158 | 0.0006 | 0.0002 | 0.0000 | 0.0002 |
| Coal Used by Industry (Non-Coking Coal) | 0.8630 | 0.0434 | 0.0251 | 0.0009 | 0.0011 | 0.0000 | 0.0011 |
| Natural Gas | 7.0271 | 0.3535 | 0.0138 | 0.0007 | 0.0049 | 0.0002 | 0.0051 |
| Nuclear | 0.3288 | 0.0165 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 5.03 | n/a | n/a | 0.10 | 0.0008 | **0.10** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix C.
b. Source: FAL 2002b.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

## Process Non-energy Emissions

Non-energy GHG emissions occur during manufacturing but are not the result of combusting fuel for energy. Data on non-process emissions were provided by FAL for $CO_2$, and $CH_4$ in units of pounds of native gas. These data were then converted to MTCE using the same methodology as in the carpet section. The process non-energy emission results for PCs are shown in Exhibit 23.[14]

**Exhibit 23. Process Non-energy Emissions Factor for Personal Computer Manufacturing**

| Gas | (a) Lbs of Gas per 1,000 Lbs of PCs | (b) Lbs of Gas per Ton of PCs (=a x 2) | (c) Metric Tons of Gas per Ton of PCs (=b / 2205 Metric Tons per Pound) | (d) MTCE/Metric Ton of Gas | (e) MTCE/Ton of PCs (=c x d) |
|---|---|---|---|---|---|
| $CO_2$ | 84.2 | 168.4 | 0.0764 | 0.27 | 0.021 |
| $CH_4$ | 1.01 | 2.02 | 0.0009 | 5.73 | 0.005 |
| **Total** | n/a | n/a | n/a | n/a | **0.026** |

Note: Totals may not sum due to independent rounding.

[14] FAL provided data on pounds of $CO_2$ and $CH_4$ per 1,000 pounds of PCs. First, these estimates were multiplied by two to convert from pounds per 1,000 pounds to pounds per short ton. Next, the estimates were converted from native gas to metric tons of carbon equivalent by dividing by the global warming potential (GWP) of each gas.

Finally, it should be noted that for most materials, a portion of the material in new production is recycled product (e.g., aluminum can production typically utilizes some recycled aluminum). In these cases, we have developed two source reduction emission factors – "current mix" and "100 percent virgin" – depending on whether the user wishes to assume that source reduction displaces only virgin product or the current mixture of virgin/recycled product. However, since PCs are currently produced using 100 percent virgin materials, the two emission factors are the same – both assume that carpet source reduction displaces 100 percent virgin materials.

The final source reduction emission factor, -15.51 MTCE/Ton, was calculated by summing the avoided process energy emissions, transportation energy emissions, and process non-energy emissions as provided in Exhibits 21 through 23.

**Recycling**

According to EPA, approximately 6 percent of PCs are recycled annually. Given the rapid growth of PC consumption and the shortening average lifespans of these products, a number of recent recycling initiatives have been undertaken by industry, EPA, and other organizations. This section describes how we developed emission factors to understand the GHG implications of these efforts.

Like carpet, PCs are also recycled in an "open loop." When PCs are recycled, they may be recycled into asphalt, steel sheet, lead bullion, CRT glass, copper wire, and aluminum sheet, as shown in Exhibit 24. Recovered plastic can be utilized as a filler component in the production of asphalt for road construction. Steel and aluminum sheet are used to produce a wide range of materials from auto parts to cookware. Recovered CRT glass can be utilized for the production of new CRT screens or processed to recover lead bullion which can be used to produce items such as batteries and X-ray shielding. Copper wire can be utilized in various electrical applications depending on its grade.

We calculated the GHG benefits of recycling PCs by comparing the difference in emissions associated with manufacturing a ton of each of the secondary products from virgin versus recycled materials, after accounting for "losses" that occur in the recycling process. The results for each of the secondary products were then weighted by the distribution shown in Exhibit 24 to obtain a composite emission factor for recycling a ton of PCs.

The calculation of avoided GHG emissions for PCs was broken up into three components: process energy, transportation energy, and process non-energy emissions. Exhibit 25 displays these results for all six secondary products after being weighted by the percentages in Exhibit 24, as well as the total GHG emission factor for recycling. Appendix D presents the raw data utilized in these calculations.

**Exhibit 24. Fate of Recycled Personal Computers, by Weight: Secondary Products and Percent Composition**

| | |
|---|---|
| Asphalt | 38% |
| Steel Sheet | 27% |
| Lead Bullion | 10% |
| CRT Glass | 2% |
| Copper Wire | 5% |
| Aluminum Sheet | 18% |

**Exhibit 25. Personal Computer Recycling Emission Factor (MTCE/Ton)**

| (a)<br>Process Energy | (b)<br>Transportation Energy | (c)<br>Process Non-Energy | (d)<br>Net Emission Factor (=a + b + c) |
|---|---|---|---|
| -0.49 | -0.01 | -0.24 | -0.74 |

To calculate each component of the recycling emission factor for the secondary products, we followed the same five steps as described above in the carpet discussion. These steps are described in detail below, with illustrative exhibits provided for "asphalt." Similar calculations were used for the other secondary products.

Step 1. Calculate the emissions for virgin production of one ton of the secondary product. As with carpet, we began by calculating emissions for virgin production by applying fuel-specific emissions coefficients to energy data for raw materials acquisition and manufacturing. The calculations for virgin process and transportation emissions for asphalt are shown in Exhibits 26 and 27, respectively. Exhibit 28 presents the estimates of process non-energy emissions for asphalt.

**Exhibit 26. Asphalt Process Energy Emissions Calculations for Virgin Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Asphalt (=0.5[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 1.0881 | 0.0054 | 0.0192 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| LPG | 0.7407 | 0.0037 | 0.0169 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Distillate Fuel | 4.8360 | 0.0242 | 0.0198 | 0.0001 | 0.0005 | 0.0000 | 0.0005 |
| Residual Fuel | 10.5587 | 0.0528 | 0.0214 | 0.0001 | 0.0011 | 0.0000 | 0.0011 |
| Diesel | 0.0000 | 0.0000 | 0.0198 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| National Average Fuel Mix for Electricity | 22.1654 | 0.1108 | 0.0157 | 0.0006 | 0.0018 | 0.0001 | 0.0018 |
| Coal Used by Industry (Non-Coking Coal) | 1.0478 | 0.0052 | 0.0251 | 0.0009 | 0.0001 | 0.0000 | 0.0001 |
| Natural Gas | 59.2419 | 0.2962 | 0.0137 | 0.0007 | 0.0041 | 0.0002 | 0.0043 |
| Nuclear | 0.2458 | 0.0012 | 0.0008 | 0.0010 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 0.5 | n/a | n/a | 0.008 | 0.0003 | **0.01** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix D.
b. Source: FAL 2002b.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 27. Asphalt Transportation Energy Emissions Calculations for Virgin Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Asphalt Transport (=0.2[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1074 | 0.0002 | 0.0192 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| LPG | 0.0771 | 0.0002 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.4003 | 0.0008 | 0.0198 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Residual Fuel | 41.9828 | 0.0840 | 0.0214 | 0.0001 | 0.0018 | 0.0000 | 0.0018 |
| Diesel | 47.2550 | 0.0945 | 0.0198 | 0.0001 | 0.0019 | 0.0000 | 0.0019 |
| National Average Fuel Mix for Electricity | 2.3432 | 0.0047 | 0.0157 | 0.0006 | 0.0001 | 0.0000 | 0.0001 |
| Coal Used by Industry (Non-Coking Coal) | 0.8592 | 0.0017 | 0.0251 | 0.0009 | 0.0000 | 0.0000 | 0.0000 |
| Natural Gas | 6.5415 | 0.0131 | 0.0137 | 0.0007 | 0.0002 | 0.0000 | 0.0002 |
| Nuclear | 0.3320 | 0.0007 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 0.2 | n/a | n/a | 0.004 | 0.0000 | **0.004** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix D.
b. Source: FAL 2002b.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 28. Asphalt Process Non-energy Emissions for Virgin Materials**

| Gas | (a) Lbs of Gas per 1,000 Lbs of Asphalt | (b) Lbs of Gas per Ton of Molded Auto Parts (=a x 2) | (c) Metric Tons of Gas per Ton of Molded Auto Parts (=b/2205 metric tons per pound) | (d) MTCE/Metric Ton of Gas | (e) MTCE/Ton of Asphalt (=c x d) |
|---|---|---|---|---|---|
| $CO_2$ | 2 | 4 | 0.0018 | 0.27 | 0.0005 |

Note: Totals may not sum due to independent rounding.

Step 2. Calculate the emissions for recycled production of one ton of the secondary product. After estimating emissions from virgin production of secondary products, we then conducted a similar analysis for recycled production. Exhibits 29, 30, and 31, show the results for process energy emissions, transportation emissions, and process non-energy emissions for molded auto parts, respectively.

**Exhibit 29. Asphalt Process Energy Emissions Calculations for Recycled Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Asphalt (=5.49[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Process Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Process Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Process Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1968 | 0.0108 | 0.0192 | 0.0001 | 0.0002 | 0.0000 | 0.0002 |
| LPG | 0.0991 | 0.0054 | 0.0169 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Distillate Fuel | 0.8490 | 0.0466 | 0.0199 | 0.0001 | 0.0009 | 0.0000 | 0.0009 |
| Residual Fuel | 1.5231 | 0.0836 | 0.0214 | 0.0001 | 0.0018 | 0.0000 | 0.0018 |
| Diesel | 0.0000 | 0.0000 | 0.0199 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| National Average Fuel Mix for Electricity | 87.0890 | 4.7812 | 0.0158 | 0.0006 | 0.0755 | 0.0028 | 0.0783 |
| Coal Used by Industry (Non-Coking Coal) | 0.9110 | 0.0500 | 0.0251 | 0.0009 | 0.0013 | 0.0000 | 0.0013 |
| Natural Gas | 8.8911 | 0.4881 | 0.0138 | 0.0007 | 0.0067 | 0.0003 | 0.0071 |
| Nuclear | 0.3389 | 0.0186 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100 | 5.49 | n/a | n/a | 0.09 | 0.0003 | **0.09** |

Note: Totals may not sum due to independent rounding.

a. Calculated using fuel-specific Btu data provided in Appendix D.

b. Source: FAL 2002b.

c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 30. Asphalt Transportation Energy Emissions Calculations for Recycled Materials**

| Fuel Type | (a) Percent of Total Btu[a] | (b) Million Btu used for Asphalt Transport (=0.98[b] x a) | (c) Fuel-specific Carbon Coefficient (MTCE/ Million Btu[c]) | (d) Fugitive $CH_4$ Emissions (MTCE/Million Btu[c]) | (e) Transport Energy $CO_2$ Emissions (MTCE/Ton) (=b x c) | (f) Transport Energy $CH_4$ Emissions (MTCE/Ton) (=b x d) | (g) Total Transport Energy Emissions (MTCE/Ton) (=e + f) |
|---|---|---|---|---|---|---|---|
| Gasoline | 0.1021 | 0.0010 | 0.0192 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| LPG | 0.0776 | 0.0008 | 0.0169 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Distillate Fuel | 0.3881 | 0.0038 | 0.0199 | 0.0001 | 0.0001 | 0.0000 | 0.0001 |
| Residual Fuel | 14.7062 | 0.1441 | 0.0214 | 0.0001 | 0.0031 | 0.0000 | 0.0031 |
| Diesel | 76.2107 | 0.7469 | 0.0199 | 0.0001 | 0.0148 | 0.0001 | 0.0149 |
| National Average Fuel Mix for Electricity | 0.6945 | 0.0068 | 0.0158 | 0.0006 | 0.0001 | 0.0000 | 0.0001 |
| Coal Used by Industry (Non-Coking Coal) | 0.8579 | 0.0084 | 0.0251 | 0.0009 | 0.0002 | 0.0000 | 0.0002 |
| Natural Gas | 6.5361 | 0.0641 | 0.0138 | 0.0007 | 0.0009 | 0.0000 | 0.0009 |
| Nuclear | 0.3268 | 0.0032 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Total** | 100% | 0.98 | n/a | n/a | 0.02 | 0.001 | **0.02** |

Note: Totals may not sum due to independent rounding.
a. Calculated using fuel-specific Btu data provided in Appendix D.
b. Source: FAL 2002b.
c. The electricity emission factor was calculated from a weighted average of fuels used in energy production in the United States. Source: EIA 2001.

**Exhibit 31. Asphalt Process Non-energy Emissions for Recycled Materials**

| Gas | (a) Lbs of Gas per 1,000 Lbs of Asphalt | (b) Lbs of Gas per Ton of Asphalt (=a x 2) | (c) Metric Tons of Gas per Ton of Asphalt (=b / 2205 Metric Tons per Pound) | (d) MTCE/Metric Ton of Gas | (e) MTCE/Ton Asphalt (=c x d) |
|---|---|---|---|---|---|
| $CO_2$ | 2.42 | 4.84 | 0.0022 | 0.27 | 0.0006 |

Note: Totals may not sum due to independent rounding.

Step 3. Calculate the difference in emissions between virgin and recycled production. The GHG savings associated with recycling were then calculated by subtracting the recycled emissions estimate from the virgin emissions estimate using the results from Steps 1 and 2. The results are shown in Exhibit 32.[15]

[15] In the case of asphalt, production from virgin materials is actually less GHG-intensive than production from recycled materials.

**Exhibit 32. Difference in Emissions Between Virgin and Recycled Asphalt Manufacture (MTCE/Ton)**

| | **Process Energy Emissions** | **Transportation Energy Emissions** | **Process Non-energy Emissions** |
|---|---|---|---|
| Virgin Manufacture | 0.01 | 0.004 | 0.0005 |
| Recycled Manufacture | 0.09 | 0.02 | 0.0006 |
| **Difference** | **-0.08** | **-0.015** | **-0.0001** |

Note: Totals may not sum due to rounding.

Step 4. Adjust the emissions differences to account for recycling losses. In the case of PCs, data indicated an 18 percent recovery-stage loss rate for PCs (i.e., 82 percent of recovered PCs for recycling were actually sent to a recycler; the remainder were landfilled). For the manufacturing stage, data indicated a 35 percent loss rate for asphalt; a .5 percent loss rate for lead bullion; and a 1 percent loss rate for copper wire. Zero manufacturing-stage losses were reported for the other secondary products.

Since losses occur in both the recovery and manufacturing stage for asphalt, the net "retention" rate was calculated as the product of the recovery and manufacturing retention rates, as shown below:

Net Retention Rate for Asphalt = Recovery Stage Retention Rate x Manufacturing Stage Retention Rate

= (100% - 18%) x (100% - 35%) = 54%

Exhibit 33 shows the calculation for adjusting the emissions differences from Step 3 for asphalt to account for recycling losses.

**Exhibit 33. Calculation of Adjusted GHG Savings for Personal Computers Recycled into Asphalt**

| | **(a)** Virgin Production (MTCE/Ton) | **(b)** Recycled Production (MTCE/Ton) | **(c)** Unadjusted GHG Savings (MTCE/Ton) (=a - b) | **(d)** Recycling Retention Rate | **(e)** Adjusted GHG Savings (MTCE/Ton) |
|---|---|---|---|---|---|
| Process Energy | 0.01 | 0.09 | -0.08 | 0.54 | -0.04 |
| Transportation Energy | 0.004 | 0.02 | -0.015 | 0.54 | -0.008 |
| Process Non-energy | 0.0005 | 0.0006 | -0.0001 | 0.54 | -0.00005 |

Note: Totals may not sum due to rounding.

Step 5. Weight the results by the percentage of recycled PCs that the secondary material comprises. Using the percentages provided in Exhibit 24, the individual GHG differences for each of the secondary products were weighted by their relative shares of recycled PCs. In the case of asphalt, the MTCE/Ton estimates from Step 4 were weighted by the percentage of recycled PCs converted to asphalt (38 percent), as shown below:

Process Energy: -0.04 $\text{MTCE/ton}_{\text{unweighted}}$ x 38 % = -0.02 MTCE/ton

Transportation Energy: -0.008 $\text{MTCE/ton}_{\text{unweighted}}$ x 38 % = -0.003 MTCE/ton

Process Non-energy: -0.00005 $\text{MTCE/ton}_{\text{unweighted}}$ x 38 % = -0.00002 MTCE/ton

The weighted results for all six secondary materials are shown in Exhibit 34.

**Exhibit 34. Personal Computer Recycling Emission Factors (MTCE/Ton)**

| Product | (a)<br><br>Process Energy | (b)<br>Transportation Energy | (c)<br><br>Process Non-Energy | (d)<br>Net Emissions (=a + b + c) |
|---|---|---|---|---|
| Asphalt | -0.02 | -0.003 | -0.00002 | -0.02 |
| Steel Sheet | 0.01 | 0.003 | 0.09 | 0.1 |
| Lead Bullion | -0.00006 | -0.005 | 0.0003 | -0.005 |
| CRT Glass | 0.0004 | -0.001 | 0.0006 | -0.0003 |
| Copper Wire | 0.02 | -0.001 | 0 | 0.02 |
| Aluminum Sheet | 0.48 | 0.02 | 0.15 | 0.65 |
| **Total** | 0.49 | 0.01 | 0.24 | **0.74** |

Note: Values may not sum due to rounding. Results for asphalt, derived in Exhibits 26 through 33, are shaded above.

**Combustion**

Approximately 15 percent of the PCs entering the municipal solid waste stream are combusted. Combustion results in both direct and indirect emissions: direct emissions from the combustion process itself and indirect emissions associated with transportation to the combustor. To the extent that PCs combusted at WTE facilities produce electricity, combustion offsets $CO_2$ emissions from electric utilities.

According to IPCC guidelines, emissions of $CO_2$ from biogenic sources are not included in GHG accounting because these emissions are assumed to be part of the natural carbon cycle.[16] However, we estimated that 12 percent of carbon in PCs is non-biogenic and that 98 percent of the non-biogenic carbon is converted to $CO_2$ during combustion.[17] Direct $CO_2$ emissions from combustion of PCs were estimated at 0.1 MTCE per ton of carpet as shown in Exhibit 35.

**Exhibit 35. Personal Computer Combustion Emissions Factor Calculation**

| Components | (a)<br><br>Percent of Total Weight of Combusted PCs | (b)<br><br>Percent Non-Biomass Carbon Content | (c)<br>Non-Biomass Carbon Content % of Total Weight (=a x b) | (d)<br><br>Factored by % Carbon to $CO_2$ (=c x 0.98) | (e)<br><br>Conversion to MTCE per ton of PCs (=d / 1.1023) |
|---|---|---|---|---|---|
| ABS (acrylonitrile-butadiene-styrene) | 8 | 84 | 7 | 7 | 0.06 |
| PPO/HIPS (Polyphenylene oxide/High Impact Polystyrene) | 6 | 85 | 5 | 5 | 0.04 |
| **Total** | | | 12 | | **0.1** |

As with other materials covered in EPA's *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks*, we estimated $CO_2$ emissions from the transportation of PCs to the WTE plant, and ash from the WTE plant to the landfill using data provided by FAL. Transportation-related $CO_2$ emissions were estimated at 0.01 MTCE.

Because most utility power plants use fossil fuels to produce electricity, the electricity produced at WTE facilities reduces the demand for fossil-derived electricity and the associated $CO_2$ emissions. Avoided utility $CO_2$

[16] See page 12 of EPA's *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks.*
[17] This calculation was based upon the percent composition of non-biogenic ABS and PPO/HIPS plastic components of PCs.

emissions were calculated based on the energy content of the carpet, the combustion efficiency of the WTE plant including transmission and distribution losses, and the $CO_2$ emissions avoided by the power plant on a per kwh basis. The estimate of emissions avoided per kwh reflects the national average mix of fuel sources and the resulting $CO_2$ emissions. As shown in Exhibit 36, carpet combustion was estimated to result in utility offsets of 0.04 MTCE per ton.

**Exhibit 36. Utility Emissions Offset From Personal Computer Combustion**

| (a)<br>Energy Content (Btu Per Pound) | (b)<br>Energy Content (Million Btu Per Ton) (=a x 0.002[a]) | (c)<br>Mass Burn Combustion System Efficiency (Percent) | (d)<br>Emission Factor for Utility-Generated Electricity (MTCE/ Million Btu of Electricity Delivered) | (e)<br>Avoided Utility $CO_2$ Per Ton Combusted at Mass Burn Facilities (MTCE) (=b x c x d) |
|---|---|---|---|---|
| 1,533 | 3.1 | 0.18 | 0.08 | 0.04 |

a. Source: FAL 2002b.

The combustion of PCs at WTE facilities also includes a steel recovery and recycling process. Approximately 90 percent of combustion facilities have ferrous recovery systems.[18] FAL reports that 1 ton of PCs contains 286 pounds of steel. Since some of this steel is lost during combustion, we included a ferrous recovery factor of 98 percent. The recycling of this recovered steel results in a $CO_2$ emissions offset of 0.12 MTCE per ton of combusted PCs.

**Exhibit 37. Steel Production Emissions Offset From Personal Computer Combustion**

| (a)<br>Tons of Steel Recovered Per Ton of Steel Combusted (Tons) | (b)<br>Percent Steel Content of PCs | (c)<br>Tons of Steel Recovered Per Ton of PCs Combusted (Tons) (=a x b) | (d)<br>Avoided $CO_2$ Emissions Per Ton of Steel Recovered (MTCE/Ton) | (e)<br>Avoided $CO_2$ Emissions Per Ton of PCs Combusted (MTCE/Ton) (=c x d) |
|---|---|---|---|---|
| 0.88 | 29% | 0.25 | 0.49 | 0.12 |

As shown in Exhibit 38, the net combustion emission factor for carpet is equal to the sum of the carpet combustion $CO_2$ emissions, transportation emissions, utility offset, and avoided emissions due to steel recovery, or 0.06 MTCE/Ton.

**Exhibit 38. PC Combustion Emission Factor (MTCE/Ton)**

| (a)<br>Combustion Emissions | (b)<br>Transportation Energy | (c)<br>Avoided Utility Emissions | (d)<br>Avoided Emissions due to Steel Recovery | (e)<br>Net Combustion Emissions (=a + b - c - d) |
|---|---|---|---|---|
| 0.10 | 0.01 | 0.04 | 0.12 | -0.06 |

### Landfilling

Roughly 77 percent of PCs entering the municipal solid waste stream are landfilled. Typically, the emission factor for landfilling is comprised of four parts: landfill $CH_4$, $CO_2$ emissions from transportation and landfill equipment, landfill carbon storage, and avoided utility emissions. However, as with other inorganic

[18] Integrated Waste Services Association, 2000. *The 2000 IWSA Waste-to-Energy Directory on United States Facilities*.

materials for which EPA has developed emission factors, there are zero landfill $CH_4$ emissions, landfill carbon storage, or avoided utility emissions associated with landfilling carpet. As a result, the emission factor for landfilling represents the $CO_2$ emissions associated with collecting the waste and operating the landfill equipment. These emissions were estimated at 0.01 MTCE per ton of carpet landfilled.[19]

## III. SUMMARY

The emission factors in this report are designed to help waste managers and others determine the GHG impacts of alternative waste management options for carpet and PCs. These factors are additions to the current factors as described in the report, *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, available online at http://www.epa.gov/mswclimate/greengas.pdf. Readers are encouraged to consult this report for more background on how life-cycle analysis is used to develop emission factors.

In addition, these factors are now part of EPA's WARM model, which provides a user-friendly way of assessing the GHG impacts of alternative waste management practice. Users simply need to enter tonnage data for the baseline and alternative waste management options, and WARM will provide the emissions results. WARM also allows users to specify some of the assumptions driving the emission factors, such as the miles of travel required to transport discarded carpet or PCs to the landfill. WARM is available online at http://www.epa.gov/global warming/actions/waste/w-online.htm.

To apply these emission factors one needs to compare the GHG results using a baseline and alternative waste management scenario. For each scenario, the GHG impact is calculated by multiplying the tonnage of carpet and/or PCs by the appropriate emission factor. For example, suppose a company is considering recycling its old carpet instead of its current (baseline) practice of landfilling the carpet. If the company generated 20 tons of carpet, the GHG benefits of recycling versus landfilling could be calculated as follows:

$$[20 \text{ tons x } -1.99 \text{ MTCE/Ton}_{recycling}] - [20 \text{ tons x } 0.01 \text{ MTCE/Ton}_{landfilling}] = 40 \text{ MTCE}$$

As the above equation shows, this one company could save 40 MTCE by recycling instead of landfilling, equivalent to removing approximately 30 cars from the road for a year.[20]

When applying the emission factors at the national level, we can see the tremendous potential for GHG emission reductions. Exhibits 39 and 40 show the current estimated carpet and PC life-cycle GHG emissions assuming the current waste disposal scenario. In addition, the exhibits show the potential reductions if all of the waste was recycled, or if 20 percent was source reduced. As the exhibits show, if all carpet was recycled, more than 5 million MTCE would be avoided, equivalent to removing over 3.5 million cars from the road for a year. If 20 percent of PCs were source reduced, nearly 3 million MTCE would be avoided, equivalent to removing over 2 million cars from the road for a year.

Finally, we close by noting that although this analysis is based upon the best available life-cycle data, uncertainties do exist in the final emission factors. In particular, the complexities arising from the fact that both PCs and carpet are composite products, and not individual materials, require that we continue to assess the assumptions and data used to develop the emission factors. As the composition, manufacturing processes, and recycling processes change in the future, these changes will be incorporated into revised factors. In addition, it should be noted that these results are designed to represent national average data. The actual GHG impacts of source reducing or recycling carpet and/or PCs will vary depending on individual circumstances (e.g., local recycling processes).

[19] FAL 1994.
[20] EPA 2003. Greenhouse Gas Equivalencies Calculator. Draft version.

**Exhibit 39. Current Baseline GHG Emissions and Reduction Potential for Carpet**

| | | Current Baseline | | | 100% Recycling | | | 20% Source Reduction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Carpet** | | | | | | | | | | |
| **Disposal Option** | **(a) EF (MTCE/ Ton)** | **(b) End of Life Fate (%)** | **(c) End of Life Fate (Tons)[a]** | **(d) Net GHG Emissions (MTCE) (=a x c)** | **(e) End of Life Fate (%)** | **(f) End of Life Fate (Tons)** | **(g) Net GHG Emissions (MTCE) (=a x f)** | **(h) End of Life Fate (%)[b]** | **(i) End of Life Fate (Tons)** | **(j) Net GHG Emissions (MTCE) (=a x i)** |
| Source Reduction | -1.11 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 514,000 | -570,540 |
| Recycling | -1.99 | 3.6 | 92,520 | -184,115 | 100 | 2,570,000 | -5,114,300 | 2.88 | 74,016 | -147,292 |
| Combustion | 0.09 | 19 | 488,300 | 43,947 | 0 | 0 | 0 | 15.2 | 390,640 | 35,158 |
| Landfilling | 0.01 | 77 | 1,978,900 | 19,789 | 0 | 0 | 0 | 61.6 | 1,583,120 | 15,831 |
| **Total** | | | | **-120,379** | | | **-5,114,300** | | | **-666,843** |

Note: Totals may not sum due to rounding.
a. This is based on an estimate of 2,570,000 tons of carpets and rugs generated in 2000, as reported in EPA 2002. This number is then multiplied by the percentages in column b to estimate tons recycled, combusted, and landfilled.
b. 20% is assumed to be source reduced. The remainder was distributed across the other waste management options using ratios from the current baseline (see column b).

**Exhibit 40. Current Baseline GHG Emissions and Reduction Potential for Personal Computers**

| | | Current Baseline | | | 100% Recycling | | | 20% Source Reduction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Disposal Option** | **(a) EF (MTCE /Ton)** | **(b) End of Life Fate (%)** | **(c) End of Life Fate (Tons)[a]** | **(d) Net GHG Emissions (MTCE) (=a x c)** | **(e) End of Life Fate (%)** | **(f) End of Life Fate (Tons)** | **(g) Net GHG Emissions (MTCE) (=a x f)** | **(h) End of Life Fate (%)[b]** | **(i) End of Life Fate (Tons)** | **(j) Net GHG Emissions (MTCE) (=a x i)** |
| Source Reduction | -15.51 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 183,380 | -2,844,224 |
| Recycling | -0.74 | 6 | 55,014 | -40,545 | 100 | 916,900 | -675,755 | 5 | 44,011 | -32,436 |
| Combustion | -0.06 | 15 | 137,535 | -8,252 | 0 | 0 | 0 | 12 | 110,028 | -6,602 |
| Landfilling | 0.01 | 77 | 706,013 | 7,060 | 0 | 0 | 0 | 62 | 564,810 | 5,648 |
| **Total** | | | | **-41,737** | | | **-675,755** | | | **-2,877,074** |

Note: Totals may not sum due to rounding.
a. This is based upon a municipal solid waste stream content of 916,900 tons of information based consumer electronics as reported in EPA 2002.
b. 20% is assumed to be source reduced. The remainder was distributed across the other waste management options using ratios from the current baseline (see column b).

## Appendix A. Data Used to Derive Carpet Source Reduction Emission Factor

**Exhibit A-1: Process Energy Data for the Production of 1,000 lbs of Residential Broadloom Carpet**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 15.7 | 0 | 15.7 | 31.4 |
| Natural Gas | 11.7 | 1.6 | 13.3 | 26.6 |
| LPG | 0.01 | 0.0011 | 0.0111 | 0.0222 |
| Coal | 0.027 | 0.22 | 0.247 | 0.494 |
| Distillate Oil | 0.042 | 0.16 | 0.202 | 0.404 |
| Residual Oil | 0.35 | 0.097 | 0.447 | 0.894 |
| Gasoline | 0.049 | 0.094 | 0.143 | 0.286 |
| Nuclear | 0 | 0.084 | 0.084 | 0.168 |
| Hydropower | 0 | 0.014 | 0.014 | 0.028 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.012 | 0.012 | 0.024 |
| **Total** | **27.88** | **2.28** | **30.16** | **60.32** |

**Exhibit A-2: Transportation Energy Data for the Production of 1,000 lbs of Residential Broadloom Carpet**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.012 | 0 | 0.012 | 0.024 |
| Natural Gas | 0.058 | 0.05 | 0.108 | 0.216 |
| LPG | 0 | 0.0005 | 0.0005 | 0.001 |
| Coal | 0 | 0.006 | 0.006 | 0.012 |
| Distillate Oil | 0 | 0.0027 | 0.0027 | 0.0054 |
| Residual Oil | 0.1722 | 0.023 | 0.1952 | 0.3904 |
| Gasoline | 0 | 0.001 | 0.001 | 0.002 |
| Nuclear | 0 | 0.0022 | 0.0022 | 0.0044 |
| Hydropower | 0 | 0.00035 | 0.00035 | 0.0007 |
| Diesel | 0.354 | 0 | 0.354 | 0.708 |
| Other | 0 | 0.00031 | 0.00031 | 0.00062 |
| **Total** | **0.60** | **0.09** | **0.68** | **1.36** |

## Appendix B. Data Used to Derive Carpet Recycling Emission Factor

(Process non-energy emissions values are located at the end of this section.)

**Exhibit B-1: Process Energy Data for the Production of 1,000 lbs of Carpet Padding Using Virgin Nylon 6,6 Fibers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 31.6 | 0 | 31.6 | 63.2 |
| Natural Gas | 17.5 | 2.58 | 20.08 | 40.16 |
| LPG | 0.0087 | 0.002 | 0.0107 | 0.0214 |
| Coal | 0.1 | 0.42 | 0.52 | 1.04 |
| Distillate Oil | 0.063 | 0.29 | 0.353 | 0.706 |
| Residual Oil | 0.57 | 0.17 | 0.74 | 1.48 |
| Gasoline | 0.068 | 0.15 | 0.218 | 0.436 |
| Nuclear | 0 | 0.16 | 0.16 | 0.32 |
| Hydropower | 0 | 0.025 | 0.025 | 0.05 |
| Other | 0 | 0.023 | 0.023 | 0.046 |
| **Total** | **49.91** | **3.82** | **53.73** | **107.46** |

**Exhibit B-2: Transportation Energy Data for the Production of 1,000 lbs of Carpet Padding Using Virgin Nylon 6,6 Fibers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.019 | 0 | 0.019 | 0.038 |
| Natural Gas | 0.08 | 0.073 | 0.153 | 0.306 |
| LPG | 0 | 0.00076 | 0.00076 | 0.00152 |
| Coal | 0 | 0.0089 | 0.0089 | 0.0178 |
| Distillate Oil | 0 | 0.0017 | 0.0017 | 0.0034 |
| Residual Oil | 0.2922 | 0.037 | 0.3292 | 0.6584 |
| Gasoline | 0 | 0.0038 | 0.0038 | 0.0076 |
| Nuclear | 0 | 0.0034 | 0.0034 | 0.0068 |
| Hydropower | 0.555 | 0.00055 | 0.55555 | 1.1111 |
| Other | 0 | 0.00049 | 0.00049 | 0.00098 |
| **Total** | **0.95** | **0.13** | **1.08** | **2.15** |

**Exhibit B-3: Process Energy Data for the Production of 1,000 lbs of Carpet Padding Using Nylon Fibers from Recycled Carpet**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 1.02 | 0 | 1.02 | 2.04 |
| Natural Gas | 0 | 0.023 | 0.023 | 0.046 |
| LPG | 0 | 0.000036 | 0.000036 | 0.000072 |
| Coal | 0 | 0.0102 | 0.0102 | 0.0204 |
| Distillate Oil | 0 | 0.0073 | 0.0073 | 0.0146 |
| Residual Oil | 0 | 0.0028 | 0.0028 | 0.0056 |
| Gasoline | 0 | 0.0013 | 0.0013 | 0.0026 |
| Nuclear | 0 | 0.0038 | 0.0038 | 0.0076 |
| Hydropower | 0 | 0.00061 | 0.00061 | 0.00122 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.00055 | 0.00055 | 0.0011 |
| **Total** | **1.02** | **0.05** | **1.07** | **2.14** |

**Exhibit B-4: Transportation Energy Data for the Production of 1,000 lbs of Carpet Padding Using Nylon Fibers from Recycled Carpet**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.034 | 0.034 | 0.068 |
| LPG | 0 | 0.00041 | 0.00041 | 0.00082 |
| Coal | 0 | 0.0044 | 0.0044 | 0.0088 |
| Distillate Oil | 0 | 0.002 | 0.002 | 0.004 |
| Residual Oil | 0 | 0.019 | 0.019 | 0.038 |
| Gasoline | 0 | 0.00053 | 0.00053 | 0.00106 |
| Nuclear | 0 | 0.0017 | 0.0017 | 0.0034 |
| Hydropower | 0 | 0.00028 | 0.00028 | 0.00056 |
| Diesel | 0.46 | 0 | 0.46 | 0.92 |
| Other | 0 | 0.00025 | 0.00025 | 0.0005 |
| **Total** | **0.46** | **0.06** | **0.52** | **1.05** |

**Exhibit B-5: Process Energy Data for the Production of 1,000 lbs of Injections Molded Auto Parts from Virgin Nylon 6,6 Fibers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 34.8 | 0 | 34.8 | 69.6 |
| Natural Gas | 17.5 | 2.64 | 20.14 | 40.28 |
| LPG | 0.0088 | 0.002 | 0.0108 | 0.0216 |
| Coal | 0 | 0.45 | 0.45 | 0.9 |
| Distillate Oil | 0.064 | 0.32 | 0.384 | 0.768 |
| Residual Oil | 0.47 | 0.17 | 0.64 | 1.28 |
| Gasoline | 0.068 | 0.16 | 0.228 | 0.456 |
| Nuclear | 0 | 0.17 | 0.17 | 0.34 |
| Hydropower | 0 | 0.027 | 0.027 | 0.054 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.024 | 0.024 | 0.048 |
| **Total** | **52.91** | **3.96** | **56.87** | **113.75** |

**Exhibit B-6: Transportation Energy Data for the Production of 1,000 lbs of Injections Molded Auto Parts from Virgin Nylon 6,6 Fibers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.019 | 0 | 0.019 | 0.038 |
| Natural Gas | 0.08 | 0.051 | 0.131 | 0.262 |
| LPG | 0 | 0.0005 | 0.0005 | 0.001 |
| Coal | 0 | 0.0061 | 0.0061 | 0.0122 |
| Distillate Oil | 0 | 0.0029 | 0.0029 | 0.0058 |
| Residual Oil | 0.3022 | 0.024 | 0.3262 | 0.6524 |
| Gasoline | 0 | 0.0012 | 0.0012 | 0.0024 |
| Nuclear | 0 | 0.0023 | 0.0023 | 0.0046 |
| Hydropower | 0 | 0.00038 | 0.00038 | 0.00076 |
| Diesel | 0.266 | 0 | 0.266 | 0.532 |
| Other | 0 | 0.00034 | 0.00034 | 0.00068 |
| **Total** | **0.67** | **0.09** | **0.76** | **1.51** |

**Exhibit B-7: Process Energy Data for the Production of 1,000 lbs of Injections Molded Auto Parts from Recycled Carpet**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 9.66 | 0 | 9.66 | 19.32 |
| Natural Gas | 0 | 0.21 | 0.21 | 0.42 |
| LPG | 0 | 0.00034 | 0.00034 | 0.00068 |
| Coal | 0 | 0.096 | 0.096 | 0.192 |
| Distillate Oil | 0 | 0.069 | 0.069 | 0.138 |
| Residual Oil | 0 | 0.026 | 0.026 | 0.052 |
| Gasoline | 0 | 0.012 | 0.012 | 0.024 |
| Nuclear | 0 | 0.036 | 0.036 | 0.072 |
| Hydropower | 0 | 0.0058 | 0.0058 | 0.0116 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0052 | 0.0052 | 0.0104 |
| **Total** | **9.66** | **0.46** | **10.12** | **20.24** |

**Exhibit B-8: Transportation Energy Data for the Production of 1,000 lbs of Injections Molded Auto Parts from Recycled Carpet**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.034 | 0.034 | 0.068 |
| LPG | 0 | 0.00041 | 0.00041 | 0.00082 |
| Coal | 0 | 0.0045 | 0.0045 | 0.009 |
| Distillate Oil | 0 | 0.002 | 0.002 | 0.004 |
| Residual Oil | 0 | 0.02 | 0.02 | 0.04 |
| Gasoline | 0 | 0.00053 | 0.00053 | 0.00106 |
| Nuclear | 0 | 0.0017 | 0.0017 | 0.0034 |
| Hydropower | 0 | 0.00028 | 0.00028 | 0.00056 |
| Diesel | 0.46 | 0 | 0.46 | 0.92 |
| Other | 0 | 0.00025 | 0.00025 | 0.0005 |
| **Total** | **0.46** | **0.06** | **0.52** | **1.05** |

**Exhibit B-9: Process Energy Data for the Production of 1,000 lbs of Carpet Backing for Carpet Tiles from Virgin Woven Polypropylene**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 14 | 0 | 14 | 28 |
| Natural Gas | 7.4 | 1.1 | 8.5 | 17 |
| LPG | 0.0041 | 0.00079 | 0.00489 | 0.00978 |
| Coal | 0 | 0.18 | 0.18 | 0.36 |
| Distillate Oil | 0.033 | 0.13 | 0.163 | 0.326 |
| Residual Oil | 0.096 | 0.07 | 0.166 | 0.332 |
| Gasoline | 0.1 | 0.065 | 0.165 | 0.33 |
| Nuclear | 0 | 0.068 | 0.068 | 0.136 |
| Hydropower | 0 | 0.011 | 0.011 | 0.022 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0098 | 0.0098 | 0.0196 |
| **Total** | **21.63** | **1.63** | **23.27** | **46.54** |

**Exhibit B-10: Transportation Energy Data for the Production of 1,000 lbs of Carpet Backing for Carpet Tiles from Virgin Woven Polypropylene**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.0086 | 0 | 0.0086 | 0.0172 |
| Natural Gas | 0.13 | 0.047 | 0.177 | 0.354 |
| LPG | 0 | 0.00041 | 0.00041 | 0.00082 |
| Coal | 0 | 0.0052 | 0.0052 | 0.0104 |
| Distillate Oil | 0 | 0.0026 | 0.0026 | 0.0052 |
| Residual Oil | 0.1413 | 0.02 | 0.1613 | 0.3226 |
| Gasoline | 0 | 0.0013 | 0.0013 | 0.0026 |
| Nuclear | 0 | 0.002 | 0.002 | 0.004 |
| Hydropower | 0 | 0.00032 | 0.00032 | 0.00064 |
| Diesel | 0.32 | 0 | 0.32 | 0.64 |
| Other | 0 | 0.00029 | 0.00029 | 0.00058 |
| **Total** | **0.60** | **0.08** | **0.68** | **1.36** |

**Exhibit B-11: Process Energy Data for the Production of 1,000 lbs of Carpet Backing Recycled Carpet**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 11.1 | 0 | 11.1 | 22.2 |
| Natural Gas | 0 | 0.25 | 0.25 | 0.5 |
| LPG | 0 | 0.00039 | 0.00039 | 0.00078 |
| Coal | 0 | 0.11 | 0.11 | 0.22 |
| Distillate Oil | 0 | 0.079 | 0.079 | 0.158 |
| Residual Oil | 0 | 0.03 | 0.03 | 0.06 |
| Gasoline | 0 | 0.014 | 0.014 | 0.028 |
| Nuclear | 0 | 0.041 | 0.041 | 0.082 |
| Hydropower | 0 | 0.0067 | 0.0067 | 0.0134 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0059 | 0.0059 | 0.0118 |
| **Total** | **11.10** | **0.54** | **11.64** | **23.27** |

**Exhibit B-12: Transportation Energy Data for the Production of 1,000 lbs of Carpet Backing Recycled Carpet**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.034 | 0.034 | 0.068 |
| LPG | 0 | 0.00041 | 0.00041 | 0.00082 |
| Coal | 0 | 0.0044 | 0.0044 | 0.0088 |
| Distillate Oil | 0 | 0.002 | 0.002 | 0.004 |
| Residual Oil | 0 | 0.019 | 0.019 | 0.038 |
| Gasoline | 0 | 0.00053 | 0.00053 | 0.00106 |
| Nuclear | 0 | 0.0017 | 0.0017 | 0.0034 |
| Hydropower | 0 | 0.00028 | 0.00028 | 0.00056 |
| Diesel | 0.46 | 0.00025 | 0.46025 | 0.9205 |
| Other | 0 | 0.00029 | 0.00029 | 0.00058 |
| **Total** | **0.46** | **0.06** | **0.52** | **1.05** |

**Exhibit B-13. Carpet Secondary Product Process Non-energy Emissions**

| | Lbs of gas per 1,000 lbs of product | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ |
| **Virgin** | | | |
| Carpet Padding | 17 | 3.76 | 6.42 |
| Injection Molded Auto Parts | 17 | 3.01 | 6.45 |
| Carpet Backing | 0 | 5.92 | 0 |
| **Recycled** | | | |
| Carpet Padding | 0 | 0 | 0 |
| Injection Molded Auto Parts | 0 | 0 | 0 |
| Carpet Backing | 0 | 0 | 0 |

## Appendix C. Data Used to Derive Personal Computer Source Reduction Emission Factor

### Exhibit C-1: Process Energy Data for the Production of 1,000 lbs of Desktop PCs

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) | (e) Adjusted Btu Based on Glass Revision[b] | (f) Adjusted Btu Based on Miscellaneous Revision[c] |
|---|---|---|---|---|---|---|
| Electricity | 436 | 0 | 436 | 872 | 872 | 873 |
| Natural Gas | 11.7 | 11 | 22.7 | 45.4 | 45.5 | 47.2 |
| LPG | 0.0022 | 0.016 | 0.0182 | 0.0364 | 0.0364 | 0.0368 |
| Metallurgical coke[a] | 2.18 | 0 | 0 | 0 | 0 | 0 |
| Petroleum coke[a] | 0.66 | 0 | 0 | 0 | 0 | 0 |
| Coal | 0.15 | 4.42 | 4.57 | 9.14 | 9.14 | 9.14 |
| Distillate Oil | 0.23 | 3.15 | 3.38 | 6.76 | 6.77 | 6.82 |
| Residual Oil | 0.47 | 1.27 | 1.74 | 3.48 | 3.49 | 3.57 |
| Gasoline | 0.017 | 0.62 | 0.637 | 1.274 | 1.275 | 1.29 |
| Nuclear | 0 | 1.65 | 1.65 | 3.3 | 3.3 | 3.3 |
| Hydropower | 0 | 0.27 | 0.27 | 0.54 | 0.54 | 0.54 |
| Diesel | 0.46 | 0 | 0.46 | 0.92 | 0.92 | 0.98 |
| Other | 0 | 0.24 | 0.24 | 0.48 | 0.48 | 0.48 |
| **Total** | **451.87** | **22.64** | **471.67** | **943.33** | **943.39** | **945.13** |

a. Since FAL data under "process non-energy" include coke-related emissions, these data were excluded from the process energy calculations (and consequently do not appear in column f of this table).

b. This adjustment is based on revised FAL estimates of the glass content in PCs. After publishing its PC report, FAL revised the glass content in PCs from 231.5 lbs to 220 lbs per 1,000 lbs of PCs. Based upon this differential we then calculated a new process energy value for glass of 2.01 Btu, an increase of 0.059 from the original value. Next, we distributed this differential by fuel type using the fuel mix for glass, and then added the differential for each fuel type to the total PC Btu estimates. The results are revised PC fuel specific energy values based upon the incremental increase of glass process energy.

c. This adjustment is based on revised FAL estimates of materials content in 1,000 lbs of PCs. The total amount of PC manufacturing materials was increased by 32 lbs to account for "miscellaneous materials" that were originally omitted from FAL's report. Because the vast majority of process energy for computer production is from wafer manufacturing, we separated out the process energy for non-wafer materials and increased the Btu values for these materials to account for the missing 32 lbs of miscellaneous materials. The assumption is that the fuel mix for the miscellaneous material content would most closely resemble the fuel mix for non-wafer materials in PCs. The result was an increase in process energy for non-wafer materials from 52.6 to 53.339 Btu.

**Exhibit C-2: Transportation Energy Data for the Production of 1,000 lbs of Desktop Personal Computers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) | (e) Adjusted Btu Based on Glass Revision[b] | (f) Adjusted Btu Based on Miscellaneous Revision[c] |
|---|---|---|---|---|---|---|
| Electricity | 0.007 | 0 | 0.007 | 0.014 | 0.014 | 0.014 |
| Natural Gas | 0.011 | 0.16 | 0.171 | 0.342 | 0.342 | 0.353 |
| LPG | 0 | 0.0019 | 0.0019 | 0.0038 | 0.0038 | 0.0039 |
| Metallurgical coke[a] | 0 | 0 | 0 | 0 | 0 | 0 |
| Petroleum coke[a] | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 0 | 0.021 | 0.021 | 0.042 | 0.042 | 0.043 |
| Distillate Oil | 0 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |
| Residual Oil | 1.375 | 0.091 | 1.466 | 2.932 | 2.933 | 3.029 |
| Gasoline | 0 | 0.0025 | 0.0025 | 0.005 | 0.005 | 0.005 |
| Nuclear | 0 | 0.008 | 0.008 | 0.016 | 0.016 | 0.017 |
| Hydropower | 0 | 0.0013 | 0.0013 | 0.0026 | 0.0026 | 0.0027 |
| Diesel | 0.745 | 0.0011 | 0.7461 | 1.4922 | 1.4922 | 1.5414 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **2.14** | **0.30** | **2.43** | **4.87** | **4.87** | **5.03** |

a. These are included only in the process non-energy emissions to avoid double counting.

b.This adjustment is based on revised Franklin Associates Ltd. glass content amounts for 1,000 lbs of PCs. The glass content was revised up from 213.5 to 220 lbs. Based upon this differential we then calculated a new transportation energy value for glass of 4.87. Next, we distributed this differential by fuel type using the fuel mix for glass, and then added the differential for each fuel type to the total PC Btu estimates. The results are revised PC fuel specific energy values based upon the incremental increase of glass process energy.

c. This adjustment is based on revised FAL materials content amounts for 1,000 lbs of PCs. The total amount of PC manufacturing materials was increased by 32 lbs to account for "miscellaneous materials" that were originally omitted from FAL's report. The transportation energy was increased from 4.87 to 5.03 Btu based upon a proportional increase in mass. We used the same fuel mix for transportation energy that had previously been reported for PCs.

## Appendix D. Data Used to Derive PC Recycling Emission Factor

(Process non-energy emissions values are located at the end.)

**Exhibit D-1: Process Energy Data for the Production of 1,000 lbs of Cold Patch Asphalt Using Virgin Aggregates**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.055 | 0 | 0.055 | 0.11 |
| Natural Gas | 0.13 | 0.017 | 0.147 | 0.294 |
| LPG | 0.0018 | 0.000038 | 0.001838 | 0.003676 |
| Coal | 0.001 | 0.0016 | 0.0026 | 0.0052 |
| Distillate Oil | 0.011 | 0.001 | 0.012 | 0.024 |
| Residual Oil | 0.024 | 0.0022 | 0.0262 | 0.0524 |
| Gasoline | 0.0018 | 0.0009 | 0.0027 | 0.0054 |
| Nuclear | 0 | 0.00061 | 0.00061 | 0.00122 |
| Hydropower | 0 | 0.000099 | 0.000099 | 0.000198 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.000088 | 0.000088 | 0.000176 |
| **Total** | **0.22** | **0.02** | **0.25** | **0.50** |

**Exhibit D-2: Transportation Energy Data for the Production of 1,000 lbs of Cold Patch Asphalt Using Virgin Aggregates**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.0024 | 0 | 0.0024 | 0.0048 |
| Natural Gas | 0 | 0.0067 | 0.0067 | 0.0134 |
| LPG | 0 | 0.000079 | 0.000079 | 0.000158 |
| Coal | 0 | 0.00088 | 0.00088 | 0.00176 |
| Distillate Oil | 0 | 0.00041 | 0.00041 | 0.00082 |
| Residual Oil | 0.0392 | 0.0038 | 0.043 | 0.086 |
| Gasoline | 0 | 0.00011 | 0.00011 | 0.00022 |
| Nuclear | 0 | 0.00034 | 0.00034 | 0.00068 |
| Hydropower | 0 | 0.000055 | 0.000055 | 0.00011 |
| Diesel | 0.0484 | 0 | 0.0484 | 0.0968 |
| Other | 0 | 0.000049 | 0.000049 | 0.000098 |
| **Total** | **0.09** | **0.01** | **0.10** | **0.20** |

**Exhibit D-3: Process Energy Data for the Production of 1,000 lbs of Asphalt Using Recycled Plastic Casings from Computers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 2.39 | 0 | 2.39 | 4.78 |
| Natural Gas | 0.17 | 0.074 | 0.244 | 0.488 |
| LPG | 0.0026 | 0.00012 | 0.00272 | 0.00544 |
| Coal | 0 | 0.025 | 0.025 | 0.05 |
| Distillate Oil | 0.0053 | 0.018 | 0.0233 | 0.0466 |
| Residual Oil | 0.033 | 0.0088 | 0.0418 | 0.0836 |
| Gasoline | 0.0013 | 0.0041 | 0.0054 | 0.0108 |
| Nuclear | 0 | 0.0093 | 0.0093 | 0.0186 |
| Hydropower | 0 | 0.0015 | 0.0015 | 0.003 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0013 | 0.0013 | 0.0026 |
| **Total** | **2.60** | **0.14** | **2.74** | **5.49** |

**Exhibit D-4: Transportation Energy Data for the Production of 1,000 lbs of Asphalt Using Recycled Plastic Casings from Computers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.0034 | 0 | 0.0034 | 0.0068 |
| Natural Gas | 0 | 0.032 | 0.032 | 0.064 |
| LPG | 0 | 0.00038 | 0.00038 | 0.00076 |
| Coal | 0 | 0.0042 | 0.0042 | 0.0084 |
| Distillate Oil | 0 | 0.0019 | 0.0019 | 0.0038 |
| Residual Oil | 0.054 | 0.018 | 0.072 | 0.144 |
| Gasoline | 0 | 0.0005 | 0.0005 | 0.001 |
| Nuclear | 0 | 0.0016 | 0.0016 | 0.0032 |
| Hydropower | 0 | 0.00026 | 0.00026 | 0.00052 |
| Diesel | 0.37312 | 0 | 0.37312 | 0.74624 |
| Other | 0 | 0.00023 | 0.00023 | 0.00046 |
| **Total** | **0.43** | **0.06** | **0.49** | **0.98** |

**Exhibit D-5: Process Energy Data for the Production of 1,000 lbs of Steel Sheet Using the Basic Oxygen Furnace**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 3.66 | 0 | 3.66 | 7.32 |
| Natural Gas | 2.27 | 0.35 | 2.62 | 5.24 |
| LPG | 0.000011 | 0.0006 | 0.000611 | 0.001222 |
| Coke | 6.61 | 0 | 6.61 | 13.22 |
| Coal | 0.046 | 0.054 | 6.664 | 13.328 |
| Distillate Oil | 0.45 | 0.037 | 0.487 | 0.974 |
| Residual Oil | 0.01 | 0.037 | 0.047 | 0.094 |
| Gasoline | 0.018 | 0.02 | 0.038 | 0.076 |
| Nuclear | 0 | 0.02 | 0.02 | 0.04 |
| Hydropower | 0 | 0.003 | 0.003 | 0.006 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.003 | 0.003 | 0.006 |
| **Total** | **13.06** | **0.52** | **20.15** | **40.31** |

**Exhibit D-6: Transportation Energy Data for the Production of 1,000 lbs of Steel Sheet Using the Basic Oxygen Furnace**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.0002 | 0 | 0.0002 | 0.0004 |
| Natural Gas | 0 | 0.039 | 0.039 | 0.078 |
| LPG | 0 | 0.00046 | 0.00046 | 0.00092 |
| Coke | 0 | 0 | 0 | 0 |
| Coal | 0 | 0.005 | 0.005 | 0.01 |
| Distillate Oil | 0 | 0.0023 | 0.0023 | 0.0046 |
| Residual Oil | 0.046 | 0.022 | 0.068 | 0.136 |
| Gasoline | 0 | 0.0006 | 0.0006 | 0.0012 |
| Nuclear | 0 | 0.0019 | 0.0019 | 0.0038 |
| Hydropower | 0 | 0.00031 | 0.00031 | 0.00062 |
| Diesel | 0.47 | 0 | 0.47 | 0.94 |
| Other | 0 | 0.00028 | 0.00028 | 0.00056 |
| **Total** | **0.52** | **0.07** | **0.59** | **1.18** |

**Exhibit D-7: Process Energy Data for the Production of 1,000 lbs of Steel Sheet Using Recycled Steel from Computers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 4.55 | 0 | 4.55 | 9.1 |
| Natural Gas | 1.29 | 0.24 | 1.53 | 3.06 |
| LPG | 0 | 0.0002 | 0.0002 | 0.0004 |
| Coal | 0.035 | 0.053 | 0.088 | 0.176 |
| Distillate Oil | 0.0032 | 0.037 | 0.0402 | 0.0804 |
| Residual Oil | 0.0019 | 0.017 | 0.0189 | 0.0378 |
| Gasoline | 0.00011 | 0.014 | 0.01411 | 0.02822 |
| Nuclear | 0 | 0.02 | 0.02 | 0.04 |
| Hydropower | 0 | 0.0032 | 0.0032 | 0.0064 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0028 | 0.0028 | 0.0056 |
| **Total** | **5.88** | **0.39** | **6.27** | **12.53** |

**Exhibit D-8: Transportation Energy Data for the Production of 1,000 lbs of Steel Sheet Using Recycled Steel from Computers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.022 | 0.022 | 0.044 |
| LPG | 0 | 0.00026 | 0.00026 | 0.00052 |
| Coal | 0 | 0.0029 | 0.0029 | 0.0058 |
| Distillate Oil | 0 | 0.0013 | 0.0013 | 0.0026 |
| Residual Oil | 0.0002 | 0.013 | 0.0132 | 0.0264 |
| Gasoline | 0 | 0.0003 | 0.0003 | 0.0006 |
| Nuclear | 0 | 0.0011 | 0.0011 | 0.0022 |
| Hydropower | 0 | 0.00018 | 0.00018 | 0.00036 |
| Diesel | 0.2914 | 0 | 0.2914 | 0.5828 |
| Other | 0 | 0.00016 | 0.00016 | 0.00032 |
| **Total** | **0.29** | **0.04** | **0.33** | **0.67** |

**Exhibit D-9: Process Energy Data for the Production of 1,000 lbs of Lead Bullion from Mined Lead Ore**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 8.38 | 0 | 8.38 | 16.76 |
| Natural Gas | 0.77 | 0.27 | 1.04 | 2.08 |
| LPG | 0 | 0.0004 | 0.0004 | 0.0008 |
| Coke | 1.78 | 0 | 1.78 | 3.56 |
| Coal | 0.0007 | 0.088 | 1.868 | 3.736 |
| Distillate Oil | 0.01 | 0.062 | 0.072 | 0.144 |
| Residual Oil | 0.062 | 0.028 | 0.09 | 0.18 |
| Gasoline | 0.0006 | 0.015 | 0.0156 | 0.0312 |
| Nuclear | 0 | 0.033 | 0.033 | 0.066 |
| Hydropower | 0 | 0.0053 | 0.0053 | 0.0106 |
| Diesel | 0.0017 | 0 | 0.0017 | 0.0034 |
| Other | 0 | 0.0047 | 0.0047 | 0.0094 |
| **Total** | **11.01** | **0.51** | **13.29** | **26.58** |

Exhibit D-10: Transportation Energy Data for the Production of 1,000 lbs of Lead Bullion from Mined Lead Ore

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.000044 | 0 | 0.000044 | 0.000088 |
| Natural Gas | 0 | 0.021 | 0.021 | 0.042 |
| LPG | 0 | 0.00025 | 0.00025 | 0.0005 |
| Coke | 0 | 0 | 0 | 0 |
| Coal | 0 | 0.0027 | 0.0027 | 0.0054 |
| Distillate Oil | 0 | 0.0013 | 0.0013 | 0.0026 |
| Residual Oil | 0.0041 | 0.012 | 0.0161 | 0.0322 |
| Gasoline | 0 | 0.00033 | 0.00033 | 0.00066 |
| Nuclear | 0 | 0.001 | 0.001 | 0.002 |
| Hydropower | 0 | 0.00017 | 0.00017 | 0.00034 |
| Diesel | 0.2724 | 0 | 0.2724 | 0.5448 |
| Other | 0 | 0.00015 | 0.00015 | 0.0003 |
| **Total** | **0.276544** | **0.0389** | **0.315444** | **0.630888** |

**Exhibit D-11: Process Energy Data for the Production of 1,000 lbs of Lead Bullion Using Recycled Lead from CRT Glass**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 8.45 | 0 | 8.45 | 16.9 |
| Natural Gas | 0.72 | 0.27 | 0.99 | 1.98 |
| LPG | 0 | 0.0004 | 0.0004 | 0.0008 |
| Coke | 1.76 | 0 | 1.76 | 3.52 |
| Coal | 0.0007 | 0.089 | 1.849 | 3.698 |
| Distillate Oil | 0.0055 | 0.063 | 0.0685 | 0.137 |
| Residual Oil | 0.06 | 0.028 | 0.088 | 0.176 |
| Gasoline | 0.0041 | 0.015 | 0.0191 | 0.0382 |
| Nuclear | 0 | 0.033 | 0.033 | 0.066 |
| Hydropower | 0 | 0.0054 | 0.0054 | 0.0108 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0047 | 0.0047 | 0.0094 |
| **Total** | **11.00** | **0.51** | **13.27** | **26.54** |

**Exhibit D-12: Transportation Energy Data for the Production of 1,000 lbs of Lead Bullion Using Recycled Lead from CRT Glass**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.000043 | 0 | 0.000043 | 0.000086 |
| Natural Gas | 0 | 0.13 | 0.13 | 0.26 |
| LPG | 0 | 0.0016 | 0.0016 | 0.0032 |
| Coke | 0 | 0 | 0 | 0 |
| Coal | 0 | 0.017 | 0.017 | 0.034 |
| Distillate Oil | 0 | 0.0079 | 0.0079 | 0.0158 |
| Residual Oil | 0.00031 | 0.076 | 0.07631 | 0.15262 |
| Gasoline | 0 | 0.002 | 0.002 | 0.004 |
| Nuclear | 0 | 0.0066 | 0.0066 | 0.0132 |
| Hydropower | 0 | 0.0011 | 0.0011 | 0.0022 |
| Diesel | 1.76273 | 0 | 1.76273 | 3.52546 |
| Other | 0 | 0.00095 | 0.00095 | 0.0019 |
| **Total** | **1.76** | **0.24** | **2.01** | **4.01** |

**Exhibit D-13: Process Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.9 | 0 | 0.9 | 1.8 |
| Natural Gas | 2.58 | 0.33 | 2.91 | 5.82 |
| LPG | 0 | 0.00058 | 0.00058 | 0.00116 |
| Coal | 0.074 | 0.029 | 0.103 | 0.206 |
| Distillate Oil | 0.3 | 0.02 | 0.32 | 0.64 |
| Residual Oil | 0.28 | 0.035 | 0.315 | 0.63 |
| Gasoline | 0.0015 | 0.017 | 0.0185 | 0.037 |
| Nuclear | 0 | 0.011 | 0.011 | 0.022 |
| Hydropower | 0 | 0.0018 | 0.0018 | 0.0036 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0016 | 0.0016 | 0.0032 |
| **Total** | **4.14** | **0.45** | **4.58** | **9.16** |

**Exhibit D-14: Transportation Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.0091 | 0.0091 | 0.0182 |
| LPG | 0 | 0.00011 | 0.00011 | 0.00022 |
| Coal | 0 | 0.0012 | 0.0012 | 0.0024 |
| Distillate Oil | 0 | 0.00016 | 0.00016 | 0.00032 |
| Residual Oil | 0.00025 | 0.0052 | 0.00545 | 0.0109 |
| Gasoline | 0 | 0.00049 | 0.00049 | 0.00098 |
| Nuclear | 0 | 0.00045 | 0.00045 | 0.0009 |
| Hydropower | 0 | 0.000073 | 0.000073 | 0.000146 |
| Diesel | 0.12457 | 0 | 0.12457 | 0.24914 |
| Other | 0 | 0.000065 | 0.000065 | 0.00013 |
| **Total** | **0.12** | **0.02** | **0.14** | **0.28** |

### Exhibit D-15: Process Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 1.08 | 0 | 1.08 | 2.16 |
| Natural Gas | 1.8 | 0.24 | 2.04 | 4.08 |
| LPG | 0 | 0.00045 | 0.00045 | 0.0009 |
| Coal | 0 | 0.025 | 0.025 | 0.05 |
| Distillate Oil | 0.22 | 0.016 | 0.236 | 0.472 |
| Residual Oil | 0.21 | 0.027 | 0.237 | 0.474 |
| Gasoline | 0 | 0.013 | 0.013 | 0.026 |
| Nuclear | 0 | 0.0093 | 0.0093 | 0.0186 |
| Hydropower | 0 | 0.0015 | 0.0015 | 0.003 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0013 | 0.0013 | 0.0026 |
| **Total** | **3.31** | **0.33** | **3.64** | **7.29** |

### Exhibit D-16: Transportation Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.088 | 0.088 | 0.176 |
| LPG | 0 | 0.001 | 0.001 | 0.002 |
| Coal | 0 | 0.011 | 0.011 | 0.022 |
| Distillate Oil | 0 | 0.0052 | 0.0052 | 0.0104 |
| Residual Oil | 0 | 0.05 | 0.05 | 0.1 |
| Gasoline | 0 | 0.0014 | 0.0014 | 0.0028 |
| Nuclear | 0 | 0.0044 | 0.0044 | 0.0088 |
| Hydropower | 0 | 0.00071 | 0.00071 | 0.00142 |
| Diesel | 2.4767 | 0 | 2.4767 | 4.9534 |
| Other | 0 | 0.00063 | 0.00063 | 0.00126 |
| **Total** | **2.48** | **0.16** | **2.64** | **5.28** |

**Exhibit D-17: Process Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 30.6 | 0 | 30.6 | 61.2 |
| Natural Gas | 15 | 3 | 18 | 36 |
| LPG | 0.000021 | 0.01 | 0.010021 | 0.020042 |
| Coal | 0.89 | 0.49 | 1.38 | 2.76 |
| Distillate Oil | 0.14 | 0.33 | 0.47 | 0.94 |
| Residual Oil | 3.2 | 0.56 | 3.76 | 7.52 |
| Gasoline | 0.025 | 0.15 | 0.175 | 0.35 |
| Nuclear | 0 | 0.18 | 0.18 | 0.36 |
| Hydropower | 0 | 0.03 | 0.03 | 0.06 |
| Diesel | 6.63 | 0 | 6.63 | 13.26 |
| Other | 0 | 0.026 | 0.026 | 0.052 |
| **Total** | **56.49** | **4.78** | **61.26** | **122.52** |

**Exhibit D-18: Transportation Energy Data for the Production of 1,000 lbs of CRT Glass from Raw Materials**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.000045 | 0 | 0.000045 | 0.00009 |
| Natural Gas | 0.000077 | 0.016 | 0.016077 | 0.032154 |
| LPG | 0 | 0.00019 | 0.00019 | 0.00038 |
| Coal | 0 | 0.002 | 0.002 | 0.004 |
| Distillate Oil | 0 | 0.0009 | 0.0009 | 0.0018 |
| Residual Oil | 0.000747 | 0.0089 | 0.009647 | 0.019294 |
| Gasoline | 0 | 0.0002 | 0.0002 | 0.0004 |
| Nuclear | 0 | 0.0008 | 0.0008 | 0.0016 |
| Hydropower | 0 | 0.00013 | 0.00013 | 0.00026 |
| Diesel | 0.202076 | 0 | 0.202076 | 0.404152 |
| Other | 0 | 0.00011 | 0.00011 | 0.00022 |
| **Total** | **0.20** | **0.03** | **0.23** | **0.46** |

**Exhibit D-19: Process Energy Data for the Production of 1,000 lbs of Copper Wire Using Recycled Copper from Computers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 26.6 | 0 | 26.6 | 53.2 |
| Natural Gas | 15.9 | 2.5 | 18.4 | 36.8 |
| LPG | 0.000021 | 0.0042 | 0.004221 | 0.008442 |
| Coal | 0.89 | 0.39 | 1.28 | 2.56 |
| Distillate Oil | 0.14 | 0.27 | 0.41 | 0.82 |
| Residual Oil | 3.2 | 0.27 | 3.47 | 6.94 |
| Gasoline | 0.025 | 0.14 | 0.165 | 0.33 |
| Nuclear | 0 | 0.15 | 0.15 | 0.3 |
| Hydropower | 0 | 0.024 | 0.024 | 0.048 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.021 | 0.021 | 0.042 |
| **Total** | **46.76** | **3.77** | **50.52** | **101.05** |

**Exhibit D-20: Transportation Energy Data for the Production of 1,000 lbs of Copper Wire Using Recycled Copper from Computers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.000045 | 0 | 0.000045 | 0.00009 |
| Natural Gas | 0.000077 | 0.072 | 0.072077 | 0.144154 |
| LPG | 0 | 0.00085 | 0.00085 | 0.0017 |
| Coal | 0 | 0.0093 | 0.0093 | 0.0186 |
| Distillate Oil | 0 | 0.0042 | 0.0042 | 0.0084 |
| Residual Oil | 0.000747 | 0.041 | 0.041747 | 0.083494 |
| Gasoline | 0 | 0.0011 | 0.0011 | 0.0022 |
| Nuclear | 0 | 0.0036 | 0.0036 | 0.0072 |
| Hydropower | | 0.00058 | 0.00058 | 0.00116 |
| Diesel | 0.953076 | 0 | 0.953076 | 1.906152 |
| Other | 0 | 0.00051 | 0.00051 | 0.00102 |
| **Total** | **0.95** | **0.13** | **1.09** | **2.17** |

**Exhibit D-21: Process Energy Data for the Production of 1,000 lbs of Aluminum Sheet from Raw Materials**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 94.4 | 0 | 94.4 | 188.8 |
| Natural Gas | 7.21 | 1.93 | 9.14 | 18.28 |
| LPG | 0.0083 | 0.0027 | 0.011 | 0.022 |
| Petroleum Coke* | 6.94 | 0 | 6.94 | 13.88 |
| Metallurgical Coke* | 1.52 | 0 | 1.52 | 3.04 |
| Coal | 0.29 | 0.45 | 7.39 | 14.78 |
| Distillate Oil | 0.22 | 0.41 | 0.63 | 1.26 |
| Residual Oil | 1 | 0.2 | 1.2 | 2.4 |
| Gasoline | 0.0046 | 0.11 | 0.1146 | 0.2292 |
| Nuclear | 0 | 0.17 | 0.17 | 0.34 |
| Hydropower | 0 | 0.027 | 0.027 | 0.054 |
| Diesel | 0.21 | 0 | 0.21 | 0.42 |
| Other | 0 | 0.024 | 0.024 | 0.048 |
| **Total** | **111.80** | **3.32** | **121.78** | **243.55** |

*These are included only in the process non-energy emissions to avoid double counting.

**Exhibit D-22: Transportation Energy Data for the Production of 1,000 lbs of Aluminum Sheet from Raw Materials**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0.012 | 0 | 0.012 | 0.024 |
| Natural Gas | 0.000077 | 0.24 | 0.240077 | 0.480154 |
| LPG | 0 | 0.0028 | 0.0028 | 0.0056 |
| Petroleum Coke* | 0 | 0 | 0 | 0 |
| Metallurgical Coke* | 0 | 0 | 0 | 0 |
| Coal | 0 | 0.031 | 0.031 | 0.062 |
| Distillate Oil | 0 | 0.014 | 0.014 | 0.028 |
| Residual Oil | 2.7413 | 0.13 | 2.8713 | 5.7426 |
| Gasoline | 0 | 0.0037 | 0.0037 | 0.0074 |
| Nuclear | 0 | 0.012 | 0.012 | 0.024 |
| Hydropower | 0 | 0.0019 | 0.0019 | 0.0038 |
| Diesel | 0.3869 | 0 | 0.3869 | 0.7738 |
| Other | 0 | 0.0017 | 0.0017 | 0.0034 |
| **Total** | **3.14** | **0.44** | **3.58** | **7.15** |

*These are included only in the process non-energy emissions to avoid double counting.

**Exhibit D-23: Process Energy Data for the Production of 1,000 lbs of Aluminum Sheet Using Recycled Aluminum from Computers**

| Fuel | (a) Combustion Process Energy per 1,000 Pounds (million Btu) | (b) Precombustion Process Energy per 1,000 Pounds (million Btu) | (c) Total Process Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Process Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 3.74 | 0 | 3.74 | 7.48 |
| Natural Gas | 3.56 | 0.48 | 4.04 | 8.08 |
| LPG | 0 | 0.00046 | 0.00046 | 0.00092 |
| Coal | 0 | 0.06 | 0.06 | 0.12 |
| Distillate Oil | 0 | 0.041 | 0.041 | 0.082 |
| Residual Oil | 0.32 | 0.035 | 0.355 | 0.71 |
| Gasoline | 0 | 0.028 | 0.028 | 0.056 |
| Nuclear | 0 | 0.022 | 0.022 | 0.044 |
| Hydropower | 0 | 0.0036 | 0.0036 | 0.0072 |
| Diesel | 0 | 0 | 0 | 0 |
| Other | 0 | 0.0032 | 0.0032 | 0.0064 |
| **Total** | **7.62** | **0.67** | **8.29** | **16.59** |

**Exhibit D-24: Transportation Energy Data for the Production of 1,000 lbs of Aluminum Sheet Using Recycled Aluminum from Computers**

| Fuel | (a) Combustion Transportation Energy per 1,000 Pounds (million Btu) | (b) Precombustion Transportation Energy per 1,000 Pounds (million Btu) | (c) Total Transportation Energy per 1,000 Pounds (million Btu) (=a + b) | (d) Total Transportation Energy per Ton (million Btu) (=c x 2) |
|---|---|---|---|---|
| Electricity | 0 | 0 | 0 | 0 |
| Natural Gas | 0 | 0.033 | 0.033 | 0.066 |
| LPG | 0 | 0.00039 | 0.00039 | 0.00078 |
| Coal | 0 | 0.0043 | 0.0043 | 0.0086 |
| Distillate Oil | 0 | 0.002 | 0.002 | 0.004 |
| Residual Oil | 0 | 0.019 | 0.019 | 0.038 |
| Gasoline | 0 | 0.0005 | 0.0005 | 0.001 |
| Nuclear | 0 | 0.0016 | 0.0016 | 0.0032 |
| Hydropower | 0 | 0.00027 | 0.00027 | 0.00054 |
| Diesel | 0.4439 | 0 | 0.4439 | 0.8878 |
| Other | 0 | 0.00024 | 0.00024 | 0.00048 |
| **Total** | **0.44** | **0.06** | **0.51** | **1.01** |

**Exhibit D-25. PC Secondary Product Process Non-energy Emissions**

| | Lbs of gas per 1000 lbs of product | | | | |
|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $CF_4$ | $C_2F_6$ |
| **Virgin** | | | | | |
| Asphalt (Cold Patch) | 2 | 0 | 0 | 0 | 0 |
| Steel Sheet | 1575 | 2.29 | 0 | 0 | 0 |
| Lead Bullion | 18.8 | 0.62 | 0 | 0 | 0 |
| CRT Glass | 181 | 0 | 0 | 0 | 0 |
| Copper Wire | 0.0036 | 0 | 0 | 0 | 0 |
| Aluminum Sheet[a] | 1690 | 0.53 | 0 | 0.31 | 0.03 |
| **Recycled** | | | | | |
| Asphalt (Cold Patch) | 2.42 | 0 | 0 | 0 | 0 |
| Steel Sheet | 26.2 | 0 | 0 | 0 | 0 |
| Lead Bullion | 17 | 0.61 | 0 | 0 | 0 |
| CRT Glass | 0 | 0 | 0 | 0 | 0 |
| Copper Wire | 0.0036 | 0 | 0 | 0 | 0 |
| Aluminum Sheet | 0 | 0 | 0 | 0 | 0 |

a. This value was revised to include 180 lbs of $CO_2$ from anode emissions.